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Quahogs in Eastern North America: Part II, History by Province and State

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On the cover:
The Warwick, R.I., statue of a quahog fisherman is surrounded by images of harvesting by rake, carrying quahogs by various boats and floats, and unloading them for market.

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Quahogs in Eastern North America: Part II, History by Province and State

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Introduction

The quahog, *Mercenaria* spp., ranging from the Canadian Maritimes to Mexico's southern State of Campeche, has long provided North Americans with a high quality food and has also been an important part of the seafood trade and sociocultural customs. Officially, the common name "northern quahog" is listed for *Mercenaria mercenaria*, which ranges from New Brunswick, Canada, into Florida, while "southern quahog" is given for *Mercenaria campechiensis*, ranging mainly from Florida to southeastern Mexico (Turgeon et., 1998). But in the industry, the term quahog is used from the Canadian Maritimes through Rhode Island, while simply clam or hard clam is used from Connecticut through Texas; in Mexico, it is the almeja (clam).

The first article (Part I) reviewed the range, biology, and ecology of quahogs, gave an historical overview of the industry (including wampum manufacture and usage and the use of quahogs in clambakes), and described harvesting gears and methods. This article (Part II) summarizes the history of the industry in specific Canadian provinces and U.S. and Mexican states, describes harvesting gears and methods (including trips with typical quahogers and wardens) in more detail, and discusses quahog enhancement programs. The authors have been professional observers of quahogs and the quahog fishery for many years. A substantial amount of the text material is based upon these observations and is unannotated. The remaining material is collected from the literature and is so cited.

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ABSTRACT – The northern quahog, Mercenaria mercenaria, *ranges along the Atlantic Coast of North America from the Canadian Maritimes to Florida, while the southern quahog,* M. campechiensis, *ranges mostly from Florida to southern Mexico. The northern quahog was fished by native North Americans during prehistoric periods. They used the meats as food and the shells as scrapers and as utensils. The European colonists copied the Indians treading method, and they also used short rakes for harvesting quahogs. The Indians of southern New England and Long Island, N.Y., made wampum from quahog shells, used it for ornaments and sold it to the colonists, who, in turn, traded it to other Indians for furs. During the late 1600's, 1700's, and 1800's, wampum was made in small factories for eventual trading with Indians farther west for furs.*

The quahoging industry has provided people in many coastal communities with a means of earning a livelihood and has given consumers a tasty, wholesome food whether eaten raw, steamed, cooked in chowders, or as stuffed quahogs. More than a dozen methods and types of gear have been used in the last two centuries for harvesting quahogs. They include treading and using various types of rakes and dredges, both of which have undergone continuous improvements in design. Modern dredges are equipped with hydraulic jets and one type has an escalator to bring the quahogs continuously to the boats. In the early 1900's, most provinces and states established regulations to conserve and maximize yields of their quahog stocks. They include a minimum size, now almost universally a 38-mm shell width, and can include gear limitations and daily quotas.

The United States produces far more quahogs than either Canada or Mexico. The leading producer in Canada is Prince Edward Island. In the United States, New York, New Jersey, and Rhode Island lead in quahog production in the north, while Virginia and North Carolina lead in the south. Connecticut and Florida were large producers in the 1990's. The State of Tabasco leads in Mexican production. In the northeastern United States, the bays with large openings, and thus large exchanges of bay waters with ocean waters, have much larger stocks of quahogs and fisheries than bays with small openings and water exchanges.

Quahog stocks in certified beds have been enhanced by transplanting stocks to them from stocks in uncertified waters and by planting seed grown in hatcheries, which grew in number from Massachusetts to Florida in the 1980's and 1990's.

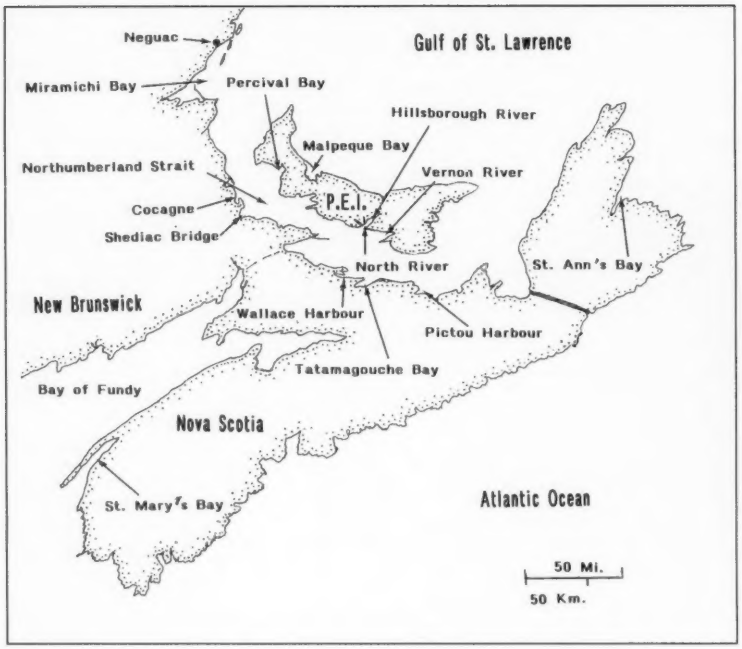

Figure 1. — Shorelines of Canadian Maritime Provinces showing locations mentioned in text.

Figure 2. — Harvesting quahogs by feeling in muddy sediments, Prince Edward Island, 1998. Photograph by A. Morrison.

History of Quahoging by Country

Canada

The Canadian Maritime provinces are at the northern end of the northern quahog's range (Fig. 1). The northernmost location where a commercial fishery ever existed was off the town of Neguac on the north side of Miramichi Bay, New Brunswick. Except for a short pulse in the 1950's, the fishery for northern quahogs in the Canadian Maritimes was relatively small until the 1970's, but it has since expanded as the demand for quahogs grew, especially in the United States which receives 90% of its landings (Jenkins et al., 1997). The fishery is concentrated in the southern Gulf of St. Lawrence. Fishermen harvest quahogs in inlets around Prince Edward Island (P.E.I.) and in New Brunswick and Nova Scotia, which border on Northumberland Strait. In addition, a new fishery in St. Mary's Bay, an arm of the Bay of Fundy, in southwestern Nova Scotia began in 1997.

The initial literature reference found regarding quahog harvesting in Prince Edward Island was by MacBride (1912), who stated the fishery was of recent origin. The quahogs were harvested with rakes having teeth 23 cm long. The quahogs were taken up with lumps of bottom or "blue mud," that was shaken out before the quahogs were removed. The demand was entirely for half-grown quahogs, because the "bull" quahogs (chowders) had a foot deemed too tough to chew. Some oystermen complained that harvesting quahogs damaged oyster beds.

The 1950's pulse in quahog production came from the Neguac area and lasted for about three years (Daigle[1]); the highest annual landings, about 2,040 t of whole quahogs (=57,000 bu, or 627,000 lb of meat), were in 1953. This Neguac stock previously had not been exploited, but recruitment to it apparently was low. The fishermen harvested the quahogs by "crawling" (Fig. 2) and removed nearly all the stock. After the fishing ended, most remnant quahogs ultimately died of a disease (Caddy and Chandler, 1976), later thought to be QPX (Landry[2]). The area no longer has a commercial fishery.

Throughout the late 1950's, 1960's, and 1970's, annual Maritimes quahog production remained below 225 t of shell stock (about 6,300 bu or 70,000 lb of meat) (Caddy and Chandler, 1976), but from 1984 through 1997 it fluctuated between 500 t (=14,000 bu, or 154,000 lb of meat) and 1,000 t (=28,000 bu, or 308,000 lb of meat). In 1998, production was 694 t (=19,500 bu, or 215,000 lb of meat) (Canada Fisheries and Oceans statistics).

On P.E.I., the most productive quahog harvesting areas are in the West, North, Hillsborough, and Vernon Rivers, and in Percival and Malpeque Bays. In New Brunswick, they are in Cocagne and the Shediac Bridge area, while in Nova Scotia they are in Wallace Harbour, Tatamagouche Bay, and Pictou Harbour. Additional small stocks exist in little inlets, such as St. Ann's Bay on the northeast shore of Cape Breton Island

[1]Daigle, O. Oyster culturist, Richibucto, New Brunswick, Canada. Personal commun., 1999.

[2]Landry, T. Government of Canada, Fisheries and Oceans, Moncton, New Brunswick. Personal commun., 1999.

(Moore[3]). On a limited scale, the stocks are harvested recreationally.

About 75% of the Maritimes quahogs currently are landed on P.E.I. by 300–400 fishermen (Jenkins[4]). The peak harvesting period is from late June to late September when water temperatures range from 10°–25°C. New Brunswick has 30–50 quahog fishermen, and Nova Scotia, where quahog harvesting has been increasing in recent years, has 100–125 quahog fishermen, of these 25 harvest in contaminated waters on the Northumberland Strait portion of Nova Scotia (Gillis[5]) and 30 harvest in St. Mary's Bay (McGuire[6]).

No one has identified the quahog predators in the Maritimes. The likely predators in the estuaries include mud crabs (family Xanthidae); rock crabs, *C. irroratus*; and starfish, *A. vulgarus* and *A. forbesi*.

Government Regulations

Fishermen who harvest quahogs for sale must possess a license issued by the Canadian Government. A limited number of licenses are issued, so new entrants must obtain a license from a person who wishes to leave the fishery.

The only closed season for clean water harvesting in the Maritimes is in Queen's County, P.E.I., where in 1998 the closed season extended from 1 May to the first Monday following 15 July. This was an experimental closure and it was continued in 1999. The harvesting of quahogs in contaminated areas for relaying was allowed in this area during this closed season. Also in 1999, Sunday and nighttime fishing was not allowed in Queen's County. The minimum lengths that quahogs can be harvested are 50 mm in P.E.I., and 38 mm in New Brunswick and Nova Scotia. In some areas, fishermen are discouraged from taking chowders to ensure that adequate spawning stocks are maintained.

Fishing Methods

Fishermen use four quahog harvesting methods: 1) "crawling" (hand picking), 2) "stomping" or "tramping" (walking), 3) raking, and 4) tonging. The first three methods are used on intertidal flats and in wading depths during low tides. Most effort takes place during large, full-moon tides when larger and less fished areas are available. The tide level ranges from 0.5–3 m in various locations in the southern Gulf of St. Lawrence.

The most common and productive method is "crawling," in which a fisherman, while crawling on hands and knees, sweeps his hands through the mud to find quahogs. The method is used in water less than 0.75 m deep and on intertidal flats. The fishermen wear gloves and usually have a container supported by a tire inner tube for flotation tied to their bodies for holding the quahogs.

When crawling in eelgrass beds, the fishermen have to wear shirts with long sleeves to protect their arms from cuts. Harvesting is easiest in areas covered by sea lettuce because the quahogs protrude above the mud-like sediments. Crawlers do not like to harvest in shelly bottoms because the shells will cut their gloves. The most productive fishermen harvest up to 5–6 hr and obtain 100 to 200 lb (1.25–2.5 bu) of quahogs/day when favorable tides occur.

"Stomping" or "tramping" involves fishermen feeling for quahogs with their feet while walking over bottoms in water depths up to 0.75 m or on bare flats. They wear stockings or neoprene booties to protect their feet from sharp shells. This method is used on firmer and sometimes sandier bottoms than those where "crawlers" harvest. The quahogs are easier to locate when the areas are covered with water than on bare flats. When a "stomper" finds a quahog, he bends over and picks it up, and, after making sure it is legal size, places it in a bucket or floating container. "Stompers" harvest about 66% as many quahogs as "crawlers" do in a day.

Fishermen rake quahogs on intertidal beaches (Fig. 3). The rakes are 15–25 cm wide and are either homemade or modified garden rakes. The raking is done mostly in firm sand and clay bottoms, often close to shore, but sometimes in rocky areas where other methods are not used. Fishermen stand and rake through the sediments. Raking in water is not effective because the quahogs are difficult to locate in the silty water stirred up by the rake. Some crawlers use rakes if they are in an area of abundant quahogs where a rake is the only suitable method (Gay[7]). Rakers usually harvest about half as many quahogs as the "crawlers," because their time available per tide is shorter.

Fishermen tong quahogs where water depths range from 0.5 to 4 m (Fig. 4). Bottoms with shells produce the most quahogs. The fishermen tong from dories 4.5 to 5 m long and propelled by 10–35 hp outboard motors. The dories have tonging boards in their bows for culling and measuring shellfish. Their anchor lines are looped around hooks on the culling boards to allow easy adjustment of their lengths. From 30 to 40 tongers work in the 3 provinces in any given summer day, and each tonger harvests 100–250 lb (1.25–3 bu) of quahogs/day.

In some areas of Prince Edward Island, fishermen who possess a clam license also harvest some quahogs in their tongs while harvesting oysters during the oyster season, which runs from 1 May to 15 July and 15 September to 30 November. The quahog bycatch is relatively small and varies in size among areas. At least half the Maritimes' quahog landings are harvested by "crawlers," while tongers harvest the least amounts. Raking and "stomping" together account for less than a third of the total.

St. Mary's Bay Fishery

In 1997, a new quahog fishery in St. Mary's Bay supported about 30 fishermen, most all of whom were experienced softshell clammers. They used modified 4–5 tine clam rakes (hacks) with short handles for harvesting quahogs. Tides in this area rise and fall an average of

[3]Moore, B. Canadian Food Inspection Agency, Sidney, Nova Scotia, Canada. Personal commun., 1999.

[4]Jenkins, J. Chief, Resource Allocation and Development, Government of Canada, Fisheries and Oceans, Charlottetown Prince Edward Island. Personal commun. 1999.

[5]Gillis, G. Canadian Food Inspection Agency, Pictou, Nova Scotia, Canada. Personal commun., 1999.

[6]McGuire, A. Innovative Fisheries Products, Digby County, Nova Scotia, Canada. Personal commun., 1999.

[7]Gay, R. Fisherman, Pownal, Prince Edward Island, Canada. Personal commun., 1999.

Figure 3. — Harvesting northern quahogs with a rake, Prince Edward Island, 1998. Photograph by A. Morrison.

Figure 4. — Harvesting eastern oysters, *Crassostrea virginica*, and northern quahogs with tongs, Prince Edward Island, 1998. Photograph by A. Morrison.

about 6 m, exposing tidal flats that may extend as far as 1.5 km from shore. The fishermen travel to the quahog grounds using vehicles called "four wheelers." At times during the summer, the fishermen can harvest during both the morning and afternoon low tides. Each harvests about 220 lb (2.75 bu) of quahogs/tide (McGuire[6]). St. Mary's Bay is closed to direct harvesting for market due to bacterial contamination, and so the quahogs have to be depurated in the Maritimes' only on-shore depuration facility, located in Digby County, N.S.

Quahog Dealers

Fishermen sell their quahogs to shellfish dealers, who also handle oysters; softshells, *Mya arenaria*; blue mussels, *Mytilus edulis;* and surfclams, *Spisula solidissima*. P.E.I. has about eight shellfish dealers who handle quahogs, New Brunswick has two, and Nova Scotia has four including the depuration plant in Digby County. The P.E.I. dealers recently began buying quahogs by the piece rather than by weight, because they were selling them by the piece. Dealing by weight became awkward because quahogs from different areas and bottom types vary in weight depending on their shell thickness and shape (Fortune[8]). In 1998, P.E.I. dealers paid per piece Can$0.20–0.24 for small, $0.17–0.19 for medium, and $0.08–0.10 for large quahogs. In New Brunswick, dealers paid about Can $1.35/lb for small, $0.65/lb for medium, and $0.15/lb for large quahogs. The fishermen truck their quahogs from the shores to the dealers' plants. Some fishermen pay other quahogers Can$1.00/bu to deliver them.

Dealers who relay contaminated quahogs must hold them for a minimum of 14 days on an approved clean-water lease for depuration before marketing them. Many quahogs harvested from closed areas in Nova Scotia are relayed to P.E.I. for depuration. Before being marketed, relayed quahogs must be tested for bacterial contamination by an approved laboratory, such as the Food Technology Center in Charlottetown, P.E.I. New Brunswick does not have a fishery for quahogs in contaminated waters. Most quahogs are taken to

[8]Fortune, B. Canadian Cove Shellfisheries, Orwell Cove, Prince Edward Island, Canada. Personal commun., 1999.

the United States in temperature-controlled trucks, and they have a 30-day shelf-life.

Recreational Fishery

Throughout their range in shallow waters in the Maritimes, quahogs are harvested by tourists and local people for home use, though softshells and surfclams are more popular with the recreationalists. A license is not required by recreational clammers, but a person cannot possess more than 50–100 quahogs depending on the location. The quahogs are gathered by "stomping," raking, or digging with forks or shovels. Quahogs harvested by recreational harvesters are not included in official landings statistics. Canadians rarely eat quahogs raw on the half-shell. Littlenecks, topnecks, and cherrystones are usually steamed and then eaten.

Quahog Culture

The three provinces have conducted culture trials with quahog seed produced in various hatcheries. The trials, initiated in the mid 1970's, have provided rather poor results due to the 6–7 yr usually required for the quahogs to attain a length of 50 mm (Kerswill, 1949) and problems with predators. In addition, substantial numbers of juveniles often die from other causes in their first winter.

Quahogs adapted for fast growth ("notata" variety) are being tested. Three known importations took place between the early 1990's and 1997. The first two were "unofficial" while the third came to P.E.I. from the Aquaculture Research Corporation in Dennis, Mass. The "notatas" were spawned in the hatchery at the Ellerslie Fisheries Station in January 1998 and growout trials now are underway in the three Maritime provinces. On P.E.I., six sites were chosen for growth trials. In the spring, seed at a mean length of 6.2 mm was planted at a density of 500/ft^2 in 16 ft^2 plastic trays containing sand. The mean size of the seed after 4 months was 14.5 mm (MacNair[9]).

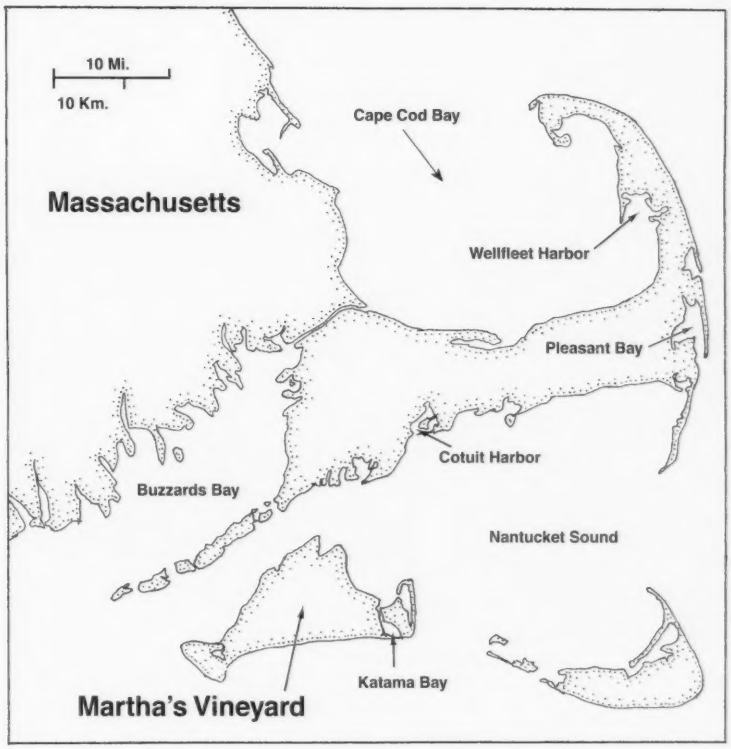

Figure 5. — Southeastern Massachusetts showing locations mentioned in text.

United States

Massachusetts

The bays in Massachusetts that have produced the most quahogs have been Wellfleet Harbor, Pleasant Bay, Cotuit Harbor, Buzzards Bay, and Katama Bay (Belding, 1912) (Fig. 5). Massachusetts towns have local control over management of their shellfish resources. It is administered by town-employed shellfish wardens or constables, who work within state regulations administered by the Massachusetts Division of Environmental Law Enforcement. The towns regulate the number of bushels, referred to as a "limit," each quahoger is allowed to land each day (Whittaker[10]).

To date, the longest historical record about quahoging in any section of the state was published in an article describing the history of shellfishing on Martha's Vineyard in a county historical magazine (MacKenzie, 1992b). The histories of the quahog fisheries in some of the other Massachusetts locations probably are similar. The history on Martha's Vineyard is presented here in lieu of an overall State history. Indian middens containing quahog shells have been found on Martha's Vineyard. One midden, on the northwest shore of Sengecontacket Pond, had quahog and bay scallop shells with some arrowheads scattered to a 60-cm depth throughout a 4-acre field. Indian middens comprised almost entirely of quahog shells also lie along some shores in the town of Marion facing Buzzards Bay; one midden is about 12 m in diameter (MacKenzie et al., 2002:Plate 1).

[9]MacNair, N. P.E.I. Dep. of Fisheries and Tourism, Prince Edward Island, Canada. Personal commun., 1999.

[10]Whittaker, D. State of Massachusetts, Division of Marine Fisheries, Pocasset, Massachusetts. Personal commun., 1999.

Several others have been covered by house construction.

The first record of commercial quahoging on Martha's Vineyard was written by Freeman (1807): "The poquau (called the quahog in the county of Barnstable) is found in Old Town (Edgartown) Harbor, at Cape Poge, and in Menemsha Pond; great quantities are exported. It is taken with iron rakes in deep water; and in shallow water it is picked up by hand. Cape Poge Pond, a lagune of salt water, affords an inexhaustible supply of poquaus and eels: Boats which are chiefly from Connecticut, frequently enter it and procure poquaus from the natives."

During the 1900's, the fishermen used short rakes, basket rakes, and bull rakes for harvesting quahogs. In the early 1900's, Edgartown had the finest littleneck fishery in Massachusetts. In 1903, the town passed a regulation forbidding the taking of quahogs under 1.5 inches across their widest part. Fishermen who used short rakes got to the beds in rowboats and sailing sharpies (Fig. 6). They put the quahogs in the boat which they towed with a rope around their waist. (Some years later, they began using a basket floated inside an automobile inner tube to hold their quahogs.) The investment required by the fishermen was small: boat, $20; rake, $3; and basket, $2. At this time, Edgartown also had about 40 long-rake fishermen who dug quahogs in 1.5–4.5 m of water from catboats and other boats. The first rake used was the basket rake, which had a pole of yellow pine 6–7 m long. Fishermen later also used bull rakes. In 1907, production of quahogs in Edgartown was 20,000 bu, which brought the fishermen about $32,000, an average of $5–$8/day/fisherman (Belding, 1912).

In about 1930, Massachusetts authorities increased the minimum size limit for quahogs to a 2-in (51-mm) diameter. A boom followed in the mid 1930's for Edgartown fishermen, because in 1930 or 1931 quahogs set densely throughout Katama Bay, and about 70 full-time and part-time fishermen raked quahogs there. About 30 regulars dug with short rakes at low tide, mostly in the bay's shallow channels in knee to waist-deep water. About 10 others dug in waters 1.5–3 m deep using basket rakes and bull rakes. The bonanza also attracted about 30 part-timers who harvested the town limit of 2 bu of littlenecks during low tides and also worked at odd jobs ashore. The littlenecks sold for $1.25 and the chowders for $0.50 a bushel. The 1938 Hurricane washed sand over most of the beds and quahogs have never been as abundant since.

During summers, in the 1920's and 1930's, one of the local markets for quahogs was a daily clambake. In addition, summer visitors also purchased littlenecks for half-shell consumption and meats from large quahogs for chowders, both of which were available from markets and peddlers. In the 1950's, littlenecks and cherrystones were offered in some island restaurants and seafood snack bars and sold for 3 for $0.10 or 12 for $0.35, but most of the quahog production was shipped to the mainland. Katama Bay still produces quahogs, and in the 1990's about 15 men, mostly teenagers and retirees, harvested them in the summer.

Darling (1984) describes additional historical details about Massachusetts quahoging in a booklet entitled, "Quahoging Out of Rock Harbor 1890–1930." Rock Harbor is an inlet in Orleans on the north shore of Cape Cod. Its fishermen raked quahogs in Cape Cod Bay. Darling (1984) said, "The safety of the quahoger depended on his boat and engine. The boat had to be able to ride out storms and to ride smoothly at anchor while raking. The first boats used out of the harbor were catboats because they were the ones immediately at hand in the 1890's. They used sails for propulsion. The shape of the cat was nearly ideal for quahoging in that it was wide for its length thereby offering a reasonably stable platform on which to work. Catboats were seldom over 26 feet (7.9 m) in length as a larger cat tended to be clumsy and less sound structurally. With the advent of gasoline powered marine engines the mast was removed and an engine installed.

"As engines became available men began to design and build their own ideas of the perfect quahoging boat. The hulls were made longer and somewhat narrower in relation to their overall length. Decks were made quite flat and the cockpit area was made smaller in relation to the size of the boat. At first there was no break in the level of the deck, but the cockpit coaming was made lower so that it didn't strike the quahoger's leg so high up when the boat rolled. Then a raised deck forward was added which gave an excellent unobstructed working surface at the bow where the launching of the rake took place. This was a mixed blessing as now the quahoger had to be sure to remember to step down to the narrow lower section of the deck, which was outside the coaming of the cockpit, whenever he had raked back to the end of the raised forward deck over the cabin.

Figure 6. — Sailing sharpie with mast lying inside (Courtesy of Mystic Seaport Museum, Mystic, Conn.).

"Usually the quahoger-built boats kept the catboat's square stern and shallow draft, but when anchored stern to the waves the square and flat construction of the stern made them pound. The seemingly obvious answer to this problem was to build double-enders which rode easily when stern to the seas. Unfortunately this design rolled excessively when the seas were quartering or broadside and had to be heavily ballasted for the sake of stability. So the square-sterned type was the best after all."

The first engines used in the catboats were the Mianus and the Lathrop. Darling (1984) said, "A single cylinder, 2-cycle Mianus engine had a flywheel, crankshaft, connecting rod and piston. On the front of the engine, between the cylinder

and the flywheel, there was an eccentric which moved a push-rod up and down. This rod operated a water pump and the moveable arm of the ignition system. These eight moving parts, some enclosed by the base and cylinder, were the engine! The electrical system consisted of four dry cells connected to a transformer-like coil which intensified the spark before it was fed to the igniter.

"A small oil reservoir on each cylinder was filled with about a cup of oil before each trip and adjusted to drip oil slowly into the crankcase. No mixing of oil and gasoline was necessary. A grease cup was connected to each of the two main bearings and was turned down half a turn or so before each trip. These engines, both one- and two-cylinder types, turned propellers up to 22 inches (56 cm) in diameter and drove the boats at a steady eight to ten knots, which was as fast as the hulls were designed to go. These engines would move the boat forward or astern equally well depending on how you started them! And, with experience, you could reverse them while running.

"The old Lathrop had no carburetor, but had a device that was called a vaporizer. Gasoline flowed into it and was sucked into the base of the engine through a small unit in which a spring held a brass ball against a collar.

"A one-cylinder 2-cycle Lathrop engine ... had a fixed point of the ignition that went through the top of the cylinder, while the moveable point, which made and broke the contact, went through the front of the cylinder. The spark was produced when these two points broke apart. 'Make and brake' was the name for this type of ignition. This mechanism was activated by a push-rod which in turn was moved by an eccentric on the crankshaft. This eccentric was really an off-center wheel on the crankshaft located between the flywheel and the base of the engine. This same eccentric worked the water pump to cool the cylinder walls. In the oldest engines the cylinder head wasn't cooled at all but this caused problems which led to a change in the design. There were no gears to operate anything — just the eccentric and the push-rod!

"The flywheels on all of these early engines were large, even massive, and had a built-in retractable brass pin to use as a crank. The spring that was supposed to pull these pins back into the flywheel when the engine started could break. This would leave the pin sticking out the full four to five inches (10–12.7 cm) of its length, whirling around with the flywheel! This was a real arm and leg breaker! After starting the engine under these conditions a board could be held at a slant in front of the spinning wheel so that the pin would hit the board thus forcing it back into the rim of the flywheel where it belonged."

The fishermen of Rock Harbor dug quahogs in the bight area of Cape Cod Bay between Wellfleet and Brewster. The water depths were 3–12 m. They carried poles for their rakes of lengths of about 8.5, 13, and 17 m. The metal rakes were about 0.75 m wide and had teeth 10 cm long. A net bag 0.75–0.9 m long was attached to hold the quahogs and trash. Besides the rake and poles, each fisherman carried a crockery jug of water to drink (Darling, 1984).

The fishermen found their digging location by sighting ranges on shore points, stakes, and buoys. Upon reaching a good location, they set out a stern and bow anchor, with the bow facing the current. The line (also known as a warp or road) between the anchors was 180 m long and was kept tight to prevent the boat from swinging back and forth. In raking quahogs, the fishermen tossed their rake into the current. The pressure of the current against the rake's handle kept the rake's teeth in the bottom. Two men could rake off a boat, one off each side. They raked the length of the boat by inching backward from bow to stern. When the areas were raked out, they let out slack on the anchor line and turned the rudder to one side, which brought them to a new area. When that area was raked out, the rudder was swung the other way and the boat moved in the opposite direction to unraked bottom. If a bottom became fished out, the anchors were reset in another location (Darling, 1984).

The daily catch/man ranged from 3 to 10 bushels; the catch depended mostly on the hours available to work. Before World War I, there were three grades of quahogs: blunts (thick bills), sharps (thin bills), and littlenecks. By the early 1920's, another grade had been added, called "counts" because they counted 100 to a bucket. They included blunts and sharps between 2.5 and 3.5 inches (6.4–8.9 cm) long. Counts today are opened and served on the half-shell as littlenecks or cherrystones (Darling, 1984).

Before 1925, most fishermen packed their quahogs in barrels and shipped them to a shellfish commission merchant in Fulton Market, New York City. They never knew what their pay would be until they got their checks. Around 1925, a local man began buying quahogs. It meant no packing and the fishermen got their checks every day. But if the price was down, the fishermen did not sell their quahogs immediately. They spread them in designated beds and took them up in the fall or early winter when the price was higher. Before World War I, the Rock Harbor fishermen got about $1.00/bushel for quahogs. During the 1920's, the price averaged about $3.50/bushel (Darling, 1984).

In the 1930's, secondhand automobile engines, many from wrecked automobiles, were installed in boats replacing the Mianus and Lathrop engines. The most common was a 4-cylinder Chevrolet engine. They had standard transmissions that were set in high gear, and forward and reverse gears were then possible. The engines were cooled with salt water which ran through the engine block. The engines were durable and many ran more than 10 years.

Information about some other Massachusetts areas over the past 50 years is available. Since the late 1940's, the Massachusetts Division of Marine Fisheries has conducted a transplanting program from polluted harbors and rivers, such as the Taunton River, which flows past Fall River into Narragansett Bay, to certified beds in Narragansett and Buzzards Bays for depuration and subsequent harvesting by fishermen. Between the mid 1960's and the early 1980's, regular annual relaying was at a rate of about 8,000 bu/yr, and the transplanting continued during the 1990's. In 1980 and 1981, State of Massachusetts surveys of quahog abundance in its pol-

luted waters of Narragansett Bay and Buzzards Bay (only areas deeper than 3.7 m were included) found the standing crop was 610,000 bu, 75% of which were chowders (Hickey, 1983).

Besides Cape Cod Bay, quahogs also grow in Buzzards Bay and Nantucket Sound, which all have oceanic waters. In the late 1940's, 10 boats using rocking chair dredges began harvesting quahogs in Buzzards Bay. Their ports were various local harbors, such as Dartmouth, New Bedford, and Fairhaven (Bourque[11]). The harvesting continued in later years, and, by the 1990's, 12–15 dredging boats, which ranged from 10 to 15 m long and used hydraulic dredges with blades 40–91 cm wide, harvested quahogs in the bay year-round, except in outer New Bedford Harbor where the season is September–June (Fig. 7). The dredging depths are 2.4–15 m (avg. 9 m). This latter depth is the maximum limit for the hose which leads to the dredge; the ratio of hose length to depth is 3:1. The catch is 90% chowders and the remainder littlenecks and cherrystones. The philosophy is "what comes aboard, stays aboard," except for seed. Individual towns now regulate the number of bushels allowed to be harvested. During the warm months, each boat is limited to 10 bu of littlenecks/day but can land unlimited quantities of the larger quahogs. During the winter, fishermen can retain all the littlenecks they can harvest because Massachusetts authorities believe they die if returned to the bottom. The boats harvest in their town waters of New Bedford (7 boats), Fair Haven (2 boats), and the Elizabeth Islands (near Cuddyhunk and Penekese Islands) (1 boat) (Whittaker[10]).

During the warm months, about 270 bull rakers, short rakers, including a few tongers, scuba divers, and treaders harvest quahogs daily in town beds around Buzzards Bay: Westport, 50; Dartmouth, 25; New Bedford, 10; Fair Haven, 30; Mattapoisett, 1; Marion, 10; Wareham, 20; Bourne, 62; and Falmouth, 60. Nearly all the Falmouth fishermen dig only in the winter because the largest beds are closed due to pollution during the warm months. The divers work only in Wareham, 1; New Bedford, 3; and Fair Haven, 6; they use a ping pong paddle with holes in it to scour away the sediments to find the quahogs. The treading is limited to a few men in Marion. Some bull rakers and tongers harvest year-round. Harvests vary by season because the quahogs are near the surface during the warm months, but burrow more deeply during the cold months putting some beyond the range of the rakes' teeth. Each bull raker harvests about 1,400 quahogs ("pieces")/day from late May through September, 1,000 quahogs/day from October through December, and 600–700 quahogs/day from January through mid May (Anderson[12]).

Figure 7. — Harvesting northern quahogs with hydraulic dredge, Buzzards Bay, Mass., mid 1990's. Photograph by D. Whittaker.

Most of the towns around Buzzards Bay each issue at least 1,200 permits to recreationalists (local resident, seniors, and non-residents) each summer. During summer weekends in good weather and a low tides, about 1,200 recreationalists dig quahogs in the towns around Buzzards Bay: Westport, 225; Dartmouth, 12; New Bedford, 12; Fair Haven, 275; Mattapoisett, 75; Marion , 20; Wareham and Onset, 50; Bourne, 530; and Falmouth, 20. In most towns, each permittee is allowed to land one peck (1/4th bu) of quahogs/week (Bourque[11]). In 1999, quahog landings by Buzzards Bay recreational diggers totaled nearly 15,000 bu, or about 25% as many as the commercial fishermen landed (Whittaker[10]). Some harvesting areas are classified as conditionally approved for digging by the Division of Marine Fisheries. The areas are closed for 5 days immediately following varying amounts of rain in different locations (Bourque[11]).

Cape Cod Bay now has a small dredge fishery for quahogs. The State allows harvesting with rocking chair dredges, but not hydraulic dredges in this bay. About 12 boats are active; 6 sail from Wellfleet and 6 sail from Orleans (Anderson[12]).

Belding (1931) mentioned a quahog fishery using dredges in Nantucket Sound from 1912 to 1915. But he said, after several years of harvesting, the beds were nearly exhausted. Between 1940 and the late 1950's, the beds were harvested sporadically by boats which sailed from ports on Cape Cod and Martha's Vineyard. In 1956, fishermen used hydraulic jet dredges to harvest the quahogs there for the first time; 5 boats were using them in the late 1950's (Ropes and Martin, 1960). Quahoging ever since has been limited in nearly all of the sound because the quahogs have been scarce (Whittaker[10]).

In May 2001, however, a large bed of quahogs, 4–5 km^2, was discovered on Handkerchief Shoals in the northeast corner of the sound about 5 km west of Monomoy Island. Its depth is 9–11 meters. In the summer of 2001, 15 boats out of a fleet of 22 boats, 13–22 m long, were harvesting the quahogs daily, each

[11]Bourque, B. Shellfish warden, New Bedford, Massachusetts. Personal commun., 1999.

[12]Anderson, M. Fisherman, Chatham, Massachusetts. Personal commun., 1999.

landed about 35 bushels of littlenecks and 35 bushels of cherrystones and chowders. They use hydraulic dredges that are 0.9–1.0 m wide. Their ports are Chatham, Hyannis, Harwich, and New Bedford. The crews observe large numbers of seed quahogs while harvesting, and so the bed may continue to produce for at least a few more years (Whittaker[10]).

Of the three states in southern New England, only Massachusetts has been active in the hatchery-growout culture of producing quahogs, while Rhode Island and Connecticut have been inactive. In 1990, at least 20% of the quahogs produced in Massachusetts resulted from hatchery seed (Anonymous, 1992). In the early 1990's, many towns spread hatchery seed over public beds and about 80 individuals in the state, each with from 0.5 to at least 10 acres of leased bottom, grew the seed (MacKenzie, 1997a).

Since the mid 1990's, about 20 towns around Cape Cod and in Buzzards Bay have purchased and grown seed for their fishermen. The seed has come from two hatcheries in Massachusetts and others in Maine, New York, and New Jersey. Before any batch of seed could be imported from the other three states, it had to be certified as disease-free by recognized authorities. The State authorities have not allowed imports of hatchery seed produced south of New Jersey, because they have feared it may carry diseases. Some towns have purchased 1-mm seed at $3–$4/1,000 and grown it in floating upwellers. It has been later grown in boxes or under screens where its survival has been as high as 80%. Town workers spread this seed over public grounds at sizes slightly smaller than littlenecks. At such sizes, few quahogs have been killed by predators. Other towns have purchased seed at about 18 mm in length, which costs $33–$35/1,000, and spread it without protection from predators. The towns involved in quahog programs have each purchased from 0.25 to 5 million seed/yr (Moles[13]). Fishermen have found higher harvests on the public beds as a result of the "seeding," but the exact contributions of the cultured quahogs to the total harvests have not been determined. In most towns, fishermen license fees for shellfishing have been raised from $25/yr to $200/yr to pay for the purchases and growing of the seed (Anderson[12]).

Figure 8. — Checking survival of seed quahogs under a predator-control net, Pleasant Bay, Ma., 1998. The quahogs were purchased from a hatchery. Photograph by C. L. MacKenzie, Jr.

The attitudes of authorities in various towns differ toward leasing bottoms. At one extreme, authorities in Wellfleet have allowed unlimited leasing of public bottoms and nearly all its bottoms now are leased. At the other extreme, authorities in Chatham, which is one of the state's most important quahog producers, and several other towns allow no leasing of public bottoms. Their authorities felt it would be too difficult to lease bottoms equitably among the towns' fishermen (Anderson[12]).

The number of individuals who now grow quahogs on their leases (grants) in Massachusetts has risen to about 250. The large increase in the quahog culturing on leases began in 1994–95. It was assisted by the Northeast Regional Office of the National Marine Fisheries Service, Gloucester, Mass., which provided about $420,000 to fund three quahog culture projects. The projects, 2 of which were training projects for fishermen, were part of an aquaculture focus through the Fishing Industry Grant Program and the Saltonstall-Kennedy Grant Program, which together supported 41 shellfish and finfish aquaculture projects costing $7.3 million during FY 1994–99. Most individuals who participated in the two quahog training projects were fishermen who had been losing substantial time finfishing due to declining stocks of groundfish and other species; the techniques learned gave them the ability sell seafood they raised themselves (Beal[14]).

Each leaseholder purchases from 10,000 to 4,000,000 seed/yr. They spread it on their leased bottoms and cover it with nets (Fig. 8). The nets have to be cleaned regularly, because they collect fouling organisms which clog the meshes in the nets and during winter silt collects under them. If the silt is not washed away, it can smother the quahogs. The survival

[13]Moles, J. State of Massachusetts, Division of Marine Fisheries, Pocasset. Personal commun., 1999.

[14]Beal, K. National Marine Fisheries Service, NOAA, Northeast Region, One Blackburn Drive, Gloucester, Massachusetts. Personal commun., 1999.

rate of quahogs from initial planting to harvesting, 28–60 months later, is about 50% (Kruczek[15]). When the quahogs attain littleneck size, they are harvested with bull rakes. Most individuals earn from $5,000 to as much as $50,000/yr from their quahog leases (Moles[13]).

With the increased number of active quahog leases in the state since 1990, the quantity of quahogs landed that was produced from hatchery seed probably has risen and it was above 20% of total quahog landings in Massachusetts. As a consequence of the increased landings, landed prices of littlenecks fell from $0.23/piece in 1995 to $0.17–$0.18/piece in 1999. The quality of hatchery quahogs is not quite as good as wild quahogs. Selected for fast growth by the hatcheries, their shelf-life is shorter, and their shells are thinner and more brittle than wild quahogs. A higher percentage of hatchery quahogs than wild quahogs is broken when sorted and counted by machines (Anderson[12]).

Trip on a Shellfish Warden's Boat: Buzzards Bay, Massachusetts, 18 May 2001

The day began at 9:30 a.m. instead of 8:00 a.m. because the warden had to prepare slips to carry to the bank in order that the fishermen the City of New Bedford had hired for harvesting quahogs would be paid. The city authorities had been awarded $289,000/year for 10 years to be allocated for: 1) shellfish relays, 2) plantings of hatchery seed quahogs, 3) law enforcement, 4) development of a 10-year management plan, and 5) administration. The money was from fines in excess of $200 million the Federal Government assessed two New Bedford companies for dumping PCB's into the harbor. The dumping forced regulatory officials to halt quahog and lobster harvesting outside the harbor; the harbor waters themselves were previously polluted and uncertified. In 2001, the city hired dredgers and bull rakers to harvest 9,800 80-pound bags of quahogs from its harbor for transplanting to certified waters in nearby New Bedford, Fair Haven, and Dartmouth. This was the first such transplant from the inner harbor since 1989. The transplanting program ran for four weeks, during which the dredgers and rakers harvested from 7 a.m. to 2 p.m. Each dredging vessel transplanted 80–110 bags/day while the hand rakers each harvested about 40 bags/day, which the wardens transplanted. The fishermen were paid $10/bag. The program was handled by the city's shellfish warden.

Between 10:00 and 10:20 a.m., the warden and his assistant raised a yellow flag on a mast on the east shore of Clarks Cove and another on the west shore of outer New Bedford Harbor. The flags signaled to the fishermen that the waters were open that day for harvesting quahogs. Raised red flags signaled the waters were closed because too much rain had fallen.

We then drove to Pope's Marina on the north side of New Bedford Harbor, and at 10:30 a.m. boarded the city's 7.6 m fiberglas boat, propelled by a 225 hp outboard motor, and headed to the other side of the harbor, a distance of 1.4 km. The sky was overcast, the air temperature was 18°C, and the wind blew gently from the southwest at 8 knots. The port of New Bedford, once the "Whaling Capital of the World," now is the "Scallop Capital of the World" because it probably is the largest scallop port in the world (nearly all scallops handled here are sea scallops, *Placopecten magellanicus;* the rest are bay scallops, *Argopecten irradians*, from Cape Cod bays); it is lined with fishing docks and marinas. On this day, most of the port's many sea scallop, otter trawl, ocean quahog, and surfclam vessels were in port because the U.S. Government landing quotas were filled.

Just inside the rugged stone hurricane barrier which protects the city's waterfront from hurricanes and other strong gales from the southwest (the barrier's height is 3.5 m above the water), we stopped and watched the two bull rakers and two dredging boats that were working in the program. The warden and his assistant's attention was focused on whether the hired fishermen would have large harvests. The fishermen sorted the quahogs by hand and tossed them into burlap bags while pushing the trash (other mollusks and shells) overboard. They were harvesting from bottom sediments consisting of mud-sand, sand, and clay. The quahogs were abundant, and the catches were good. Each raker had at least twenty 80-pound bags of quahogs aboard after 4 hr of raking. The warden and his assistant took aboard 24 bags from one boat, and we left the area to transplant them.

We went through the opening in the hurricane barrier (gates can be swung to close this opening when strong winds are forecast) and headed southward and then westward toward the west side of Clarks Cove, a distance of 7 km from the harbor. En route, the warden dumped one of the bags into a tub and picked out the quahogs, leaving the trash (mostly live chains of quarterdecks, *Crepidula fornicata*) in the tub. He said the bags had too much trash, and he would scold the fisherman about it. We arrived at the planting site at 11:38 a.m., and, as we drifted slowly, he and his assistant dumped all the quahogs out of the bags into the water, which was 2–3 m deep, in 5 min; they saved the bags for the rakers to fill later in the week. Inshore of us, one quahoger was diving for quahogs, and off the north shore of the cove a bull raker was harvesting quahogs and a fisherman in a boat was trolling for bluefish. The beds of relayed quahogs will be opened for direct to market harvesting in 90 days, or earlier if recertified by the Massachusetts Division of Marine Fisheries.

We returned to New Bedford Harbor and the warden told the fisherman that he had included too much trash with the quahogs in his bags. The fisherman said he would cull more carefully. We then went over to chat with the warden of the Town of Dartmouth who was in another fiberglas boat. He had taken aboard 20 bags of quahogs from the other bull raker to spread on a bottom in Dartmouth waters 9 km southwest of New Bedford. Only one dredge boat remained working, because the gear on the second one was broken and it went to a dock for repairs. We returned to Pope's Marina at 2:50 p.m., our day was finished, and the warden and his assistant were pleased with the way things went.

[15]Kruczek, B. Fisherman, Orleans, Massachusetts. Personal commun., 1999.

Rhode Island

Commercial quahoging in Rhode Island was first recorded in the 1870's, when about 75 fishermen harvested quahogs in the state (Ingersoll, 1887) (Fig. 9). Fishermen rowed their boats to the beds and harvested quahogs with tongs (Desbonnet and Lee, 1991). By the early 1900's, some fishermen were towed to the beds by motor boats (Boyd, 1991), and by the late 1930's many had their own outboard motors to propel their boats. In the 1940's, when the oyster industry in Narragansett Bay had declined, the quahog fishery grew in importance (Fig. 10). During World War II, about 40 boats, 9–10.6 m long, using rocking chair dredges (Fig. 11), joined the tonging fleet harvesting quahogs. Each dredging boat was limited by state regulation to 40 bu/day. This fishery ended in 1956.

From the late 1800's to the early 1920's, Rhode Island landings of quahogs totaled about 15,000 bu/yr, but afterward production increased and reached 425,000 bu in 1955. It fell afterward as the state banned dredging and closed some beds due to pollution (Boyd, 1991), and the quahogs may have become scarcer, perhaps as starfish became abundant (Pratt et al., 1992). Production fell to 210,000 bu in 1974, but rose again to 350,000 bu/yr in the 1980's.

The Rhode Island Department of Environmental Management regulates the quahog fishery (Fig. 12). The principal management involves: 1) limiting the sizes of quahogs which fishermen can harvest to at least 1.0 inch in width (about 1.5 inches long); 2) restricting harvests to clean waters; and 3) transplanting quahogs from polluted to certified public bottoms for depuration and subsequent harvesting by the fishermen.

About 33% of the quahog grounds in Narragansett Bay are polluted and uncertified for direct marketing. Located mainly in the north end of the bay, some grounds contain large concentrations of quahogs. Most polluted grounds are closed to harvesting for direct sales to markets, but some with the lowest bacteria counts are opened during dry weather. When it rains steadily and at least 12.5 mm of rain falls, water runoff from land and overflows from sewers force the state to close those grounds for at least 7 days. If at least 25 mm of rain falls, bed closures last 10 days (Ganz[16]).

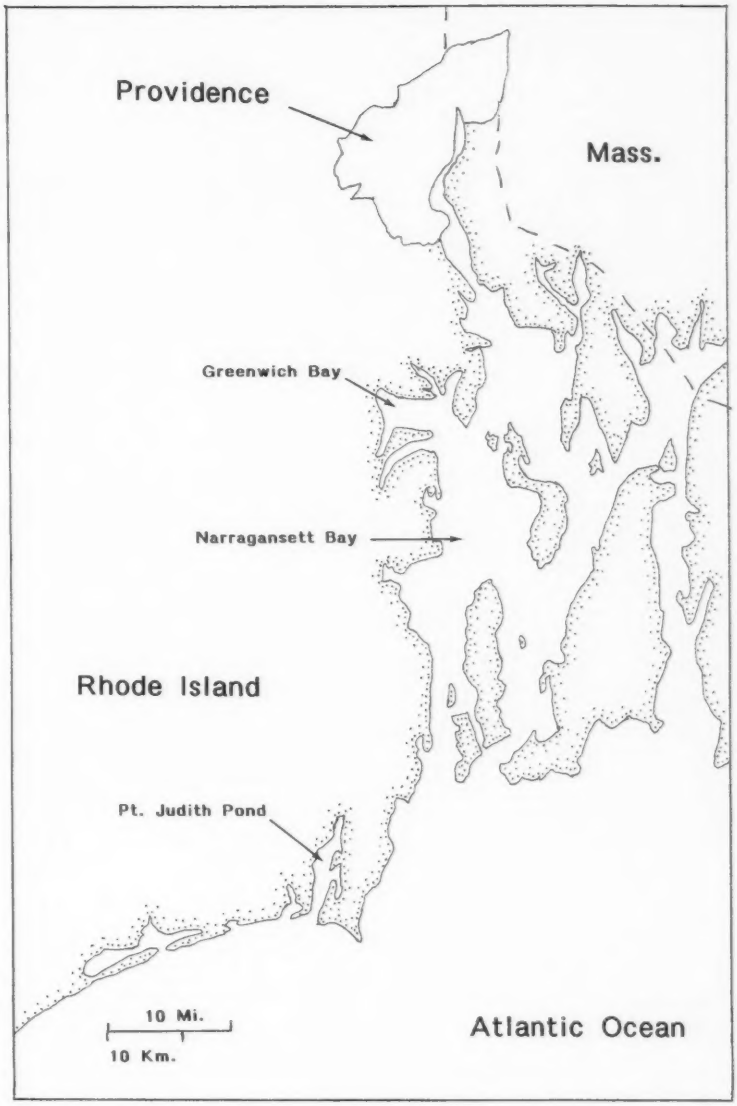

Figure 9. — Narragansett Bay area showing locations mentioned in text.

Since the late 1970's, the state has hired quahog fishermen to rake up and transplant polluted quahogs to certified areas, paying them, in the 1990's, $0.10/lb of quahogs. Each year, about 125 fishermen were so employed. Each harvested about 1–1.5 t (35–40 bu)/day. From 1977 to 1998, from 7 to 322 t (200–4,000 bu), with an average of 98 t

[16]Ganz, A. Department of Natural Resources, State of Rhode Island, Wakefield. Personal commun., 1999.

Figure 10. — Rhode Island fishermen in their rowboats harvesting quahogs with bull rakes, late 1940's (from Tressler and Lemon, 1951).

Figure 12. — Technicians recording data during State of Rhode Island survey of quahog beds in Narragansett Bay, 1998. Photograph by C. L. MacKenzie, Jr.

Figure 11. — Rhode Island fishermen harvesting quahogs with a rocking chair dredge, late 1940's (from Tressler and Lemon, 1951).

(2,700 bu)/yr of quahogs have been relayed. A new relay program began in 1997 that involves relaying quahogs from the Providence River using dredge boats. A survey showed the river had a standing crop of 26,400 t (750,000 bu) of quahogs. In 1998, the dredging boats moved 238 t (6,665 bu) from the river while the hand rakers moved 290 t (8,100 bu) from various polluted areas to certified areas. The quahogs are transplanted in the spring, and the state delays the opening of the beds for harvesting by fishermen until the fall to give the quahogs opportunity to spawn and provide a new set of seed to the beds and surrounding areas. State officials would prefer the quahogs be left for 2 spawning years before they are harvested, but that plan was not yet implemented in 1998 (Rice et al., 2000; Ganz[16]).

During the 9 months from September 1998 through May 1999, about 250 Rhode Island fishermen harvested quahogs with bull rakes every day in certified waters when the price was sufficiently high — at least $0.19–$0.20/littleneck. Fewer diggers harvest if the price falls to around $0.12/littleneck. In the 3 summer months, the number of fishermen increases to nearly 500, when students, teachers, and others enter the fishery (Lazar[17]). Most diggers trailer their boats daily from their homes to the shores, launch them, and return home with them afterward. The trailering allows them the mobility to move among various harvesting areas. Such mobility is important because Narragansett Bay and the nearby salt ponds have many inlets and coves, and in windy weather the fishermen usually can find sheltered places to rake quahogs (Ganz[16]).

In addition, 40–50 scuba divers harvest quahogs. The state limits each diver to no more than 12 bu of quahogs/day (Ganz[16]).

The bull rakers once wanted the state to ban quahog harvesting by scuba divers (Fleet, 1992), and, in the early 1990's, a verbal "war" raged between the rakers and divers. The rakers believed the divers enjoyed a substantial harvest advantage over them because individual divers could harvest more quahogs than could individual bull rakers. But, in that period, earnest planning for quahog hatchery and growout culture in Rhode Island began, and both groups opposed it. The rakers and divers "cemented together" in opposition and have since got along well (Ganz[16]).

State quahog landings have fallen sharply since the mid 1980's when about 1,000 fishermen were digging quahogs. In 1998, landings were 62,000 bu. The major cause of the production decline has been a drop in the numbers of fishermen, because job opportunities ashore increased due to a robust state

[17]Lazar, N. State of Rhode Island Fish and Game Department, Wakefield. Personal commun., 1999.

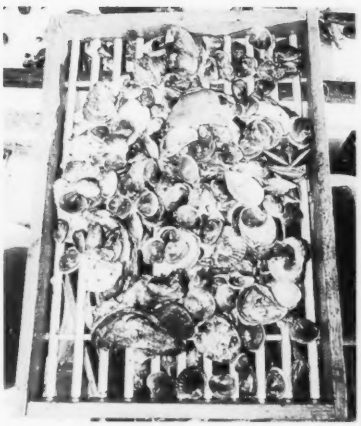

Figure 13. — Quahogs and "trash" after being dumped from rake into hand sorter. Photograph by C. L. MacKenzie, Jr.

Figure 14. — Rhode Island fisherman washing his catch of quahogs, Great Salt Pond, 1998. Photograph by C. L. MacKenzie, Jr.

economy many abandoned quahoging (Valliere[18]). In the 1980's, quahog fishermen were having difficulty finding places to dock their boats and park their boat trailers (MacKenzie, 1997a), but this problem eased during the 1990's due to the reduced numbers of fishermen (Valliere[18]).

Quahog culture is almost non-existent in Rhode Island. In 1998 only a few acres of bottom were leased, mostly for growing oysters. One reason for the absence of quahog culture is that the quahog fishermen are strongly opposed to it because leases would remove some bottoms from which they could harvest quahogs. Nearly all bottoms where salinities exceed 15‰ already have quahogs in them. Also, the fishermen fear hatchery quahogs would compete in markets with wild quahogs. Another fear is the fast-growing, thin-shelled hatchery stocks might interbreed with the wild quahogs and reduce their quality. Rhode Island state authorities do not allow a hatchery to sell quahogs that are less than 1 inch in width as is allowed in some other states (Lazar[17]). Individual rakers currently earn more money per day than the only leaseholder who has been growing and selling hatchery-growout quahogs.

In recent years, on summer weekends when the weather is good, at least 1,000 recreationalists harvest quahogs along the shallows in Narragansett Bay and coastal ponds. They wade and tread or use short rakes for harvesting (Ganz[16]).

Trip on a Quahog Raking Boat: Great Salt Pond, R.I., 18 August 1998

The fisherman, 45 years old, harvests quahogs in various bays and ponds in Rhode Island using a bull rake from his 6.7 m fiberglass boat propelled by a 150 hp outboard motor. Every day, he tows his boat and trailer with his pickup truck from his home to harvesting sites. In 1997, he harvested quahogs 320 days, during which he raked 4–5 hr/day. He believes if he rakes more hours each day, he will wear himself out and have to quit this work at an earlier age than he wishes because he enjoys it. He likes raking in the winter best, because he does not become too warm. He has a reputation for making large harvests of quahogs in relatively hard bottoms, while many other diggers can outdo him in soft bottoms.

On this day, he worked in Great Salt Pond (Pt. Judith Pond) on the southwest shore of Rhode Island. Low hills rise from narrow unspoiled marshes on the shorelines along both sides of the pond. The trees and shrubs growing on the hills look wild and natural; some residential homes are scattered among them. The north end of the pond is narrow and has a ramp which quahogers and sport fishermen use to launch their boats.

The fisherman launched his boat at this ramp at 5:55 a.m., and we traveled into the pond. The water visibility was at least 2 m: No bloom of algae from excess nutrients was present here. At a distance 2.5 km from the boat ramp, he "cut" the engine, we stopped over an underwater ridge, about 2 m below us, and he began raking at 6:08 a.m. As he was harvesting, he usually put the suitcase rake over, raked for 1–2 min, left the rake idle for a minute or two and culled his previous harvest in his hand sorter (Fig. 13), and then continued raking. He consistently pulled up the rake for emptying 3–5 min after he put it over (Fig. 14). Upon seeing many oyster shells in his rake, he said the highest survival of quahog seed is in beds where shells or gravel or both, are abundant because, he thought, predators have difficulty finding them in such bottoms.

[18]Valliere, A. State of Rhode Island Fish and Game Department, Wakefield. Personal commun., 1999.

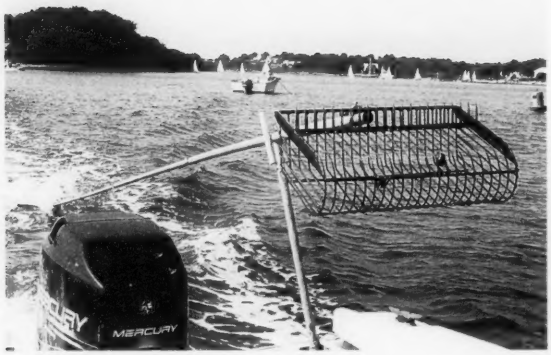

Figure 15. — When a Rhode Island fisherman moves between grounds, he puts his rake on a stand and trails its handle behind in the water. Photograph by C. L. MacKenzie, Jr.

Figure 16. — Harvest of littlenecks and topnecks in Great Salt Pond, R.I., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 17. — Most Rhode Island quahogers trailer their boats between their homes and the harvesting sites each day. Photograph by C. L. MacKenzie, Jr.

The wind blew at 10–15 knots, or too light to push the boat away from the rake sufficiently, and so he had to push the boat himself using the rake. After he had jerked (pulled) the rake about 12 times, he had to push the boat about 1 meter away from the rake and then he could continue jerking it ("push and pull," as he called the action). He used two 3-m aluminum sections of handle with his rake; the cross-handle was bent at a slight angle for comfort. After he emptied the quahogs from his rake into his sorter, he put the rake over again, then raked a little, and stopped to sort. Sorting involved picking out the large shells from the sorter, putting the sorter over the water, and shaking out the seed through the openings. He then emptied the legal-size quahogs into two white PVC buckets which held sufficient saltwater to cover them. His quahog catches were good and he brought up lots of seed. It appeared from the quantity of seed present, that any quahog predators, which might have been here at times in the past, were currently scarce in the pond.

During the day, he harvested in three pond locations (Fig. 15). His final raking was at 10:50 a.m. He had made 40 rakings and harvested 1,400 quahogs, an average of 35 legal-sized quahogs/raking (range, 19–55 quahogs/raking) (Fig. 16). About 1,300 of the quahogs were littlenecks; at a selling price of $0.195 cents each, they would bring him about $254; the remaining 100 cherrystones would sell for about $10, or more than enough to pay for the fuel used by his outboard motor and truck. We arrived back at the boat ramp just after 11 a.m. He loaded his boat on his trailer (Fig. 17) and drove to a dealer to sell his quahogs. From there, he drove home.

In overview, over the past few years quahogs have remained abundant in Rhode Island, perhaps because of the reduced harvesting effort. The fisherman said, "We keep taking quahogs and they keep coming." The 12 or so quahogers in Great Salt Pond appeared content. They were making good money, they saw lots of seed, and they were pleased with actions (transplanting quahogs from polluted grounds, and preventing aquaculture interests from leasing quahoging bottoms) taken by the State Department of Environmental Management.

Connecticut

Before the 1980's, commercial quahog harvests in Connecticut (Fig. 18) were

relatively small compared with nearby states, in part because the fishing industry had concentrated on oysters. In the 1920's and 1930's, about 50 fishermen in the entire state were harvesting quahogs with bull rakes, but there was little bull raking after that. In 1946, the first quahog dredges came to Connecticut, when oyster companies in Norwalk and New Haven got three rocking chair dredges from Rhode Island. They used them from oyster boats during the late summer when oyster culturing and harvesting were slow. In 1958, the companies replaced the rocking chair dredges with the more efficient hydraulic dredges and then used them on three or four boats (MacKenzie, 1997a).

All Connecticut quahog harvesting grounds are leased from the state, and it is illegal to harvest quahogs commercially on public grounds. In 1970 in the entire state, six boats, all owned by oyster companies, were harvesting quahogs part-time using hydraulic dredges. In that year, fishermen discovered a large stock of littlenecks and cherrystones on broad tidal flats in upper Norwalk Harbor, where they never had been known to occur abundantly before. Because the waters were uncertified, the state allowed the Tallmadge Company of South Norwalk and other fishermen to transplant the quahogs to their certified leased beds for depuration. Harvesting only during high tides with hydraulic dredges, the fishermen transplanted and later harvested several thousand bushels of quahogs before the stock was depleted later in the year.

In the late 1980's and 1990's, Connecticut quahog production surged after quahog abundances erupted. In the late 1980's, fishermen found quahogs distributed over much larger areas than they once were. The grounds, encompassing hundreds of acres of state-controlled public grounds, were at distances from about 0.5 km to as far as 4 km from the shores and at depths to 15 m (Williams[19], Bloom[20], Hopp[21], White[22]). The fishermen leased many acres of the grounds from the state so they could harvest the quahogs. Most leases were 100–200 acres in area. They were obtained on a competitive basis through closed bids. The annual lease rates for most ranged from $50 to $200/acre/yr, but some leases went for as high as $1,000/acre.

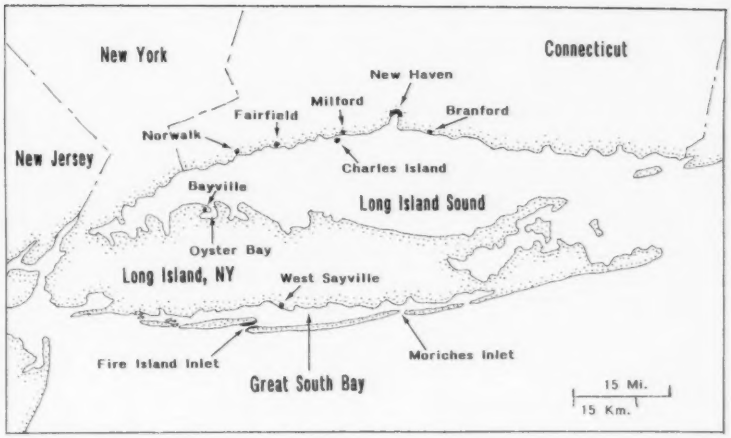

Figure 18. — The shorelines of Connecticut and Long Island, N.Y., showing areas mentioned in text.

The big quahog production years were from 1986 to 1996. In the mid 1990's, about 50 quahog boats were harvesting daily, year-round. Many boats were standard Nova Scotia-style boats that had been used for potting lobsters. They were fitted with hydraulic dredges and pumps for harvesting quahogs (Volk[23]). After 1996, some beds became depleted, state quahog production fell, and, by 1999, 30 boats remained harvesting daily (Hopp[21]). None of the leased beds were planted with hatchery quahogs.

MacKenzie and Pikanowski (2000) believe quahogs became abundant in the late 1980's because starfish had become scarce in Connecticut. The starfish had been abundant between 1957 and the late 1970's.

Trip on a Quahog Dredging Boat: Long Island Sound, February 1998

The trip involved a day of harvesting quahogs in Long Island Sound on a boat that berthed at a dock in Milford Harbor (Fig. 18). Measuring 10.7 m long, 4.6 m wide, and drawing 1.2 meters, the boat, 17 years old, had a hull made of ferrocement and wood, a new deck, A-frame, and pilot house, and it was powered by a 471 Detroit Diesel engine (Fig. 19). Its captain and 2 deckhands, who made up the crew, harvested quahogs with a hydraulic dredge; its dredging bar was 46 cm wide with 14 teeth set almost parallel to the bottom, and with 11 jets at its front to soften the bottom and 5 jets aimed backward to drive the quahogs back into the dredge's cage. The deck of the boat had two tables. One was a culling table that measured about 1.5 × 2 m, stood waist high, and was located about 2.5 m from the pilothouse against the port rail. The other was a mechanical sorting table with an attached quahog counter that stood against the boat's starboard rail.

The captain held three leases, one in Milford, one in Fairfield, and another in Branford (Fig. 18). He regularly transplanted seed and market-sized quahogs

[19]Williams, L. Fisherman, Milford, Connecticut. Personal commun., 1998.

[20]Bloom, H. Owner, Tallmadge Oyster Company, South Norwalk, Connecticut. Personal commun., 1999.

[21]Hopp, D. Oyster fisherman, Tallmadge Oyster Company, South Norwalk, Connecticut. Personal commun., 1999.

[22]White, G. Foreman, Tallmadge Oyster Company, Bridgeport, Connecticut. Personal commun., 1999.

[23]Volk, J. State of Connecticut, Department of Agriculture, Aquaculture Division, Milford. Personal commun., 1999.

from the Fairfield and Branford leases to the Milford lease, located just 2.5 km from Milford Harbor. By doing this, he was able to harvest quahogs when strong southerly winds prevented his boats from running the 18 km to Fairfield or the 21 km to Branford each way to get quahogs for orders.

Considered by his peers as one of the best quahog harvesters in Connecticut, the captain complained the weather this autumn was too warm and too calm. It meant no harvesting areas were closed due to covers of ice and strong winds, and all quahogers along the entire coast from Massachusetts to Florida could harvest at least a few days a week. The markets consequently were glutted with quahogs, he could not sell all he could harvest, and the price had declined by 2–3 cents/quahog from last summer. During the past few weeks, this crew harvested about 3 days a week, and on those days he harvested only enough quahogs to fill the buyers' orders, or about 66% of the quantity he could have harvested.

The captain related some observations about this fishery:

1) More small quahogs survive in beds with large quantities of shells;

2) If a bed has a good mixture of quahog sizes, seed to chowders, thus showing a good history of setting and survival, the quahogs probably will continue to set. But if a bed contains but one or two sets of quahogs, it may be risky to spend much money obtaining a lease for the bed because its quahog abundance may be temporary;

3) Jetting water from a quahog dredge changes the bottom substrate (fine sands are brought to its surface) and also vibrates the surrounding sediments, forcing the quahogs to burrow deeper where they cannot be harvested. The dredgers have to abandon the ground for a few months to allow the quahogs to rise closer to the surface.

4) A dredge must be heavy enough to stay on the bottom, but not be too heavy or it will sink into the bottom. He estimates his dredge, which weighs 136 kg out of water, weighs perhaps 32–36 kg when jetting the bottom.

5) When the boat begins dredging on a shelly bottom, it often gets about 20% quahogs and 80% oyster shells in the dredge. After a while, the ratio becomes 60% quahogs and 40% shell.

Figure 19. — Quahog harvesting boat that uses a hydraulic dredge, Milford, Conn., 1998. Photograph by C. L. MacKenzie, Jr.

On this day, the buyer wanted the quahogs to be packed in 3-peck onion bags (4 pecks are in a bushel). Each bag would hold either 400 littlenecks, 300 topnecks, 150 cherrystones, or 100 chowders. We left the dock in Milford at 7:45 a.m. and went to the captain's Milford lease about 1.5 km west of Charles Island. It was cloudy and damp, a wind of about 5 knots blew from the shore in a northeasterly direction, and the sea was calm while the air temperature was about 6°C. The bed was about 7.5 m below the water surface. Its sediments consisted of a mixture of sand, gravel, and oyster shells.

The captain dropped the dredge to the bottom the first time at 8:20 a.m. It was retrieved 4 min later, emptied onto the culling table, and returned to the bottom by 8:25 a.m. The two deckhands, who wore short boots, caps, and oilskin pants and jackets over their clothes, stood on opposite sides of the culling table, picked out the quahogs, tossed them into a wire basket, and pushed the shells overboard as the boat was moving ahead (Fig. 20). The first catch was 1.5 pecks of quahogs. One deckhand hosed the mud off the quahogs in the basket (Fig. 21) and then put them on the mechanical sorting table and pushed them onto the rollers. After that, the dredge was lifted, emptied, and lowered about once every 5 min. The catches ranged from 1 to 4 pecks/lift. The deckhands were consistently busy emptying the dredge, culling and washing, pushing shells off the culling table, putting the quahogs onto the mechanical sorting table, and removing the onion bags from the base of the sorting table as they became full of quahogs, tying their tops tightly, and stacking the bags in front of the pilot house. About every 45 min, the crewmen shortened the length of the towing rope because the tide was falling, and they occasionally took 5-min breaks to snack or quench their thirst.

The crew quit dredging at 1:40 p.m., and we arrived at the dock in Milford Harbor at 2:15 p.m., with 22 bags of littlenecks, 22 bags of topnecks, 9 bags of cherrystones, and 2 bags of chowders, the total the buyer could sell (Fig. 22). The quahogs were carried into a walk-in cooler at the edge of the shore; it measured 2 m wide, 2.1 m high, and 4.25 m deep (Fig. 23). The buyer's refrigerated truck would arrive within a few hours and take the quahogs to the Fulton Fish Market in Manhattan, which opens at midnight.

Figure 20. — Culling quahogs from trash on hydraulic dredging boat, Milford, Conn., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 21. — Culling and washing quahogs on hydraulic dredging boat, Milford, Conn., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 22. — Unloading harvested quahogs at Milford, Conn., 1998. Each bag and basket contains a specific size and number of quahogs. Photograph by C. L. MacKenzie, Jr.

Figure 23. — Placing harvested quahogs in small cooler, Milford, Conn., 1998. Photograph by C. L. MacKenzie, Jr.

The captain would be paid $70–$72/400-count sack of littlenecks, $60/300-count sack of topnecks, $16/150-count sack of cherrystones, and $10/100-count sack of chowders. His gross for the day was $3,046.

Long Island, N.Y.

Long Island, N.Y., has been a major producer of quahogs, with harvests coming mainly from four bays on its north shore and Great South Bay (Fig. 18). In the 1870's, about 700 harvesters were active, each gathering about 3 bu/day (Ingersoll, 1887). Production continued afterward with the combined harvests from the north shore bays being about equal to that from Great South Bay (Fig. 24).

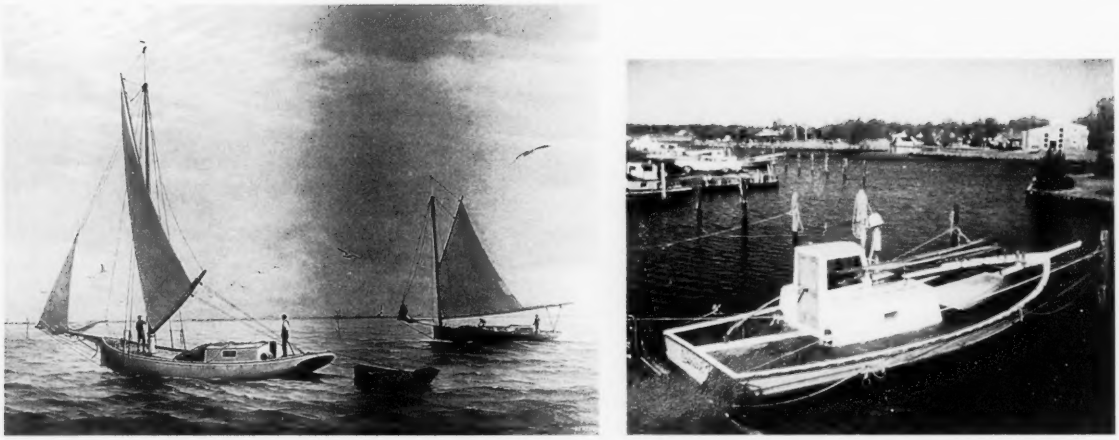

Figure 24. — Small sloops once used for dredging oysters (left) were later engine-driven and used for tonging quahogs during the 1930's and beyond, Great South Bay, N.Y. (right).

Following a survey he made of the mollusk fisheries of Long Island, James L. Kellogg (1901) said the quahog supply in the town grounds from Freeport to Patchogue in Great South Bay was enormous. Fishermen harvested it with tongs. He said:

"Opposite Fire Island inlet is the town of Islip, which has always been the center of the industry in (Great South) bay. Soon after the civil war, a factory for canning clams (northern quahogs) was established there. After struggling for several years to perfect the process of canning, and to obtain a market, the business grew to such proportions that 400 bushels (10,000 cans) of hard clams were canned daily. This output continued for years, clams being brought from all parts of the bay. About five years ago, the supply began to decrease. Two years ago, it became impossible to obtain clams, and today very few are canned there. The demand had steadily increased, and is now greater than ever. In order to keep its business, this company established another factory in one of the southern states (Florida?)." Kellogg believed the quahog supply fell because oyster companies had reduced the quahog harvesting areas when they covered many of the grounds with oysters.

From the 1940's into the 1980's, the New York bays often produced the bulk of quahogs in the United States (Fig. 25). The percentage of total U.S. landings coming from New York reached about 50% in 1947. It dropped afterward to just under 20% in 1954, then rose steadily to slightly above 60% of the total in 1978, and remained slightly above 50% of the total until 1980 (McHugh, 1991). The landings afterward fell to about 25% of the total in 1984 and to 17% in the early 1990's, particularly as Great South Bay's production declined sharply (MacKenzie and Burrell, 1997).

In the 1940's (Fig. 26) and 1950's, most fishermen used tongs in Great South Bay and they dug mostly on former oyster beds that had large quantities of surface shells. The quahogs were more abundant on those beds than on beds without the shell cover, probably because the shells hid juvenile quahogs from predators. In the 1960's and 1970's, the fishermen, whose numbers had increased sharply by then, used mostly bull rakes. The raking removed most of the shells and the extent of the shelly bottoms was substantially reduced. Quahogs remain most abundant in bottoms with large quantities of shell fragments mixed with sand (MacKenzie, 1997a).

In the early 1900's, the oyster industry dominated shellfishing in Great South Bay. Oyster production, high until about 1920, fell afterward until by 1930 it had fallen to less than half the peak amount. While oystering flourished, it employed most of the local fishermen. As mentioned in Part I in the section on bay and ocean water exchange, the 1931 hurricane broke an inlet through the beach at Moriches Bay and the increased water exchange with the ocean led to a huge increase in quahog abundances (McHugh, 1991). But duck farms on the bay's north shore brought some negative changes. The duck farming had begun in about 1890. By 1924, about 1.5 million ducks were being raised, and by 1941 their numbers increased to a peak of about 6 million. Effluents from the duck farms washed into the bay, phosphates became extremely high, and nitrates declined in the water. Dense blooms of *Nannochloris* spp. resulted, the waters became yellow-green, and the ciliary tracts of shellfish became clogged with the algae. The blooms lasted from the 1930's through the mid 1950's. Scientists from the Woods Hole Oceanographic Institute in Massachusetts believed reduced tidal exchange between the bay and ocean through Fire Island Inlet and resultant stagnant waters aided the blooms' growth (Black and Kassner, 1988; McHugh, 1991).

In 1951, Moriches Inlet closed after years of shoaling, but Hurricane Edna reopened it in 1953. The result again was good quahog growth. By 1957, a shallow delta formed inside the inlet and the inlet nearly refilled again. In 1958, the inlet was dredged and subsequently

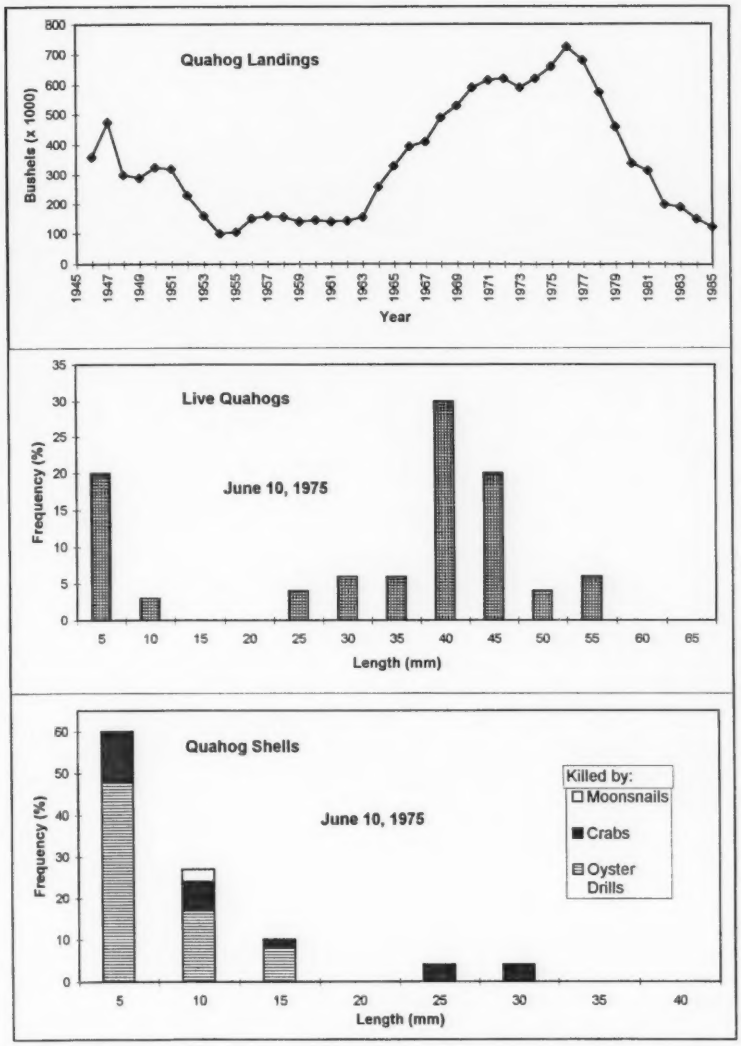

Figure 25. — Data from Great South Bay, N.Y. The upper panel illustrates historical landings in New York (McHugh, 1991). The middle panel shows there were few seed quahogs in the presence of a large number of adult quahogs in 1975 (MacKenzie, 1977). In lower panel, histobars representing the sizes of northern quahogs killed by predators illustrate predation is heaviest on the smallest quahogs (from MacKenzie, 1977).

protected by seawalls. Around this time, duck farm production began to decline and the farms began to treat the duck wastes. Authorities had learned that when Moriches Inlet was closed water quality in Great South Bay deteriorated and salinities declined, and, conversely, when the inlet was open, increased flushing improved water quality and salinity increased (Kassner and Black, 1982; McHugh, 1991).

In two years in the early 1960's, quahogs set densely throughout most of Great South Bay, and, because the bay's quahogs grow slowly, the sets remained as seed and littlenecks for several years. By the mid 1960's a few thousand fishermen were harvesting the quahogs; most were landing 5–10 bu/day. During the most productive period in the 1970's, total production was slightly above 700,000 bu in each of the three best years (Anonymous, 1987) (Fig. 25). After the late 1970's, the bay's quahog production declined sharply.

It might appear overharvesting by the many fishermen in the bay during the 1970's was responsible for the decline in quahog landings during the late 1970's, but data by MacKenzie (1977) showed light sets had occurred during at least four consecutive years when relatively large quantities of mature quahogs were present (Fig. 25). It appears instead that adverse environmental factors affecting quahog spawning and larval development, rather than a dearth of mature quahogs, were mainly responsible for the falling stock. In addition, blue crabs, which are ravenous predators of small quahogs, became abundant during and after the 1980's and were also responsible. Adverse environmental conditions continued into the 1990's as the inlets allowed too little exchange of bay and ocean waters to flush out the "brown tides" that prevent normal feeding, spawning, and growth of quahogs.

In 1999, only 50 men raked each day on the public bottoms of the bay. Each raker usually harvested 800–1,000 quahogs/day, but when the quahogs burrowed more deeply into the sediments during heat waves, the yield dropped to 600–800 quahogs/day.

Trip on a Quahog Escalator Harvesting Boat: Great South Bay, 29 July 1998

The Bluepoints Company owns 90 km^2 of bottom in Great South Bay through grants issued by English King Charles II in 1664 and continuing through various regents until 1693; the same bottom has remained in the company's hands ever since (Strong[24]). The water depth over this bottom, which is level except for a

[24]Strong, C. Bluepoints Co., West Sayville, New York. Personal commun., 1999.

few narrow channels, is about 2 meters. The company has been harvesting quahogs from these grounds for at least half a century, and currently contracts 4 escalator dredge boats to harvest them, after recently idling its own fleet of about 10 escalator harvesters because harvests were small. The contract boats are 15 m long and have decks entirely enclosed by steel walls (2.1 m high) and ceilings (Fig. 27). Their escalator belts are 15 m long, 46 cm wide, and their heads at the bottom are 70 cm wide. Quahogs, oyster shells, and chunks of sand held together with mud come up the belts and drop onto the ends of waist-high rubber belts, that move the material across the sterns of each boat. Each boat is operated by one fisherman who dredges for 8 hr/day, 7 days/week, but is idle every other Sunday. The usual harvest is about 7 bu of quahogs/boat/day, but summer heat waves drive the quahogs deeper into the sediments and the catch is often half as large. The fisherman on this boat believes the quahogs are about evenly distributed across the company's bottoms.

Figure 26. — Fishermen measuring out his quahog harvest from Great South Bay, N.Y., with dealer, early 1940's (from Glancy, 1943).

We set off for the bay from the company's dock in West Sayville. The town is known for its long shellfishing history, first as an oystering center and now as a quahoging port. The land at West Sayville is low and flat, and the shoreline along the north side of the bay has homes, many of mansion size, along most of it. As we headed into the bay, the water appeared brownish from an algal bloom. Upon reaching a harvesting site near the middle of the lease at 8:20 a.m., the fisherman started the hydraulic pump, lowered the head of the escalator dredge to the bottom, and set the steering wheel so the boat would turn in circles that appeared to be about half a kilometer in diameter. As the day passed, the wind and current moved the boat slowly westward so it consistently harvested on new ground. The fisherman felt certain the quahogs were scarce in the bay because Fire Island Inlet was too small, allowing little exchange of bay and ocean waters. He related when the quahogs were abundant during the 1960's and 1970's the opening was wider.

As quahogs came across the rubber belt (running from left to right if facing the stern), the fisherman picked out the quahogs, and tossed them into three hand sorters, each 50 cm^2 lying beside one another (Fig. 28). Their grate bars were spaced to retain the quahogs >1 in (25.4 mm) wide. The seed fell through onto the belt and, with shells and chunks of sediments, passed off the belt overboard to the right. As the fisherman filled the sorters, he emptied the quahogs into bushel PVC baskets (Fig. 29).

The escalator belt broke at 12:20 p.m. after 4 hr of dredging, and we had to return to the dock. The harvest was 2 bu of littlenecks (800/bu) (Fig. 30). The company pays the fisherman $48 a bushel. In this half-day, he used 20 gallons of fuel, and so this was not a very profitable day for him or the company: the expenses were $20 for fuel plus the cost of the belt repairs.

Trip on a Quahog Dredging Boat: Oyster Bay, 1 July 1998

Oyster Bay, N.Y., has two groups of fishermen harvesting quahogs. One is the F. M. Flower Company that controls part of the bay bottom through leases and harvests quahogs with hydraulic dredges, and the other is comprised of about 50 independent men who harvest on public bottoms using bull rakes (Fig. 31).

During the winter of 1997–98, the company had stocked a section of its leased bottom along the west shore of the bay by transplanting quahogs onto it from another lease near the town of Oyster Bay. Bacterial counts on this latter lease were too high for the quahogs to be marketed. The company now was harvesting quahogs from the stocked lease; the water depth there ranged from 1.5 to 3 m. The harvesting boat was a typical oyster boat, about 15 m long (Fig. 32), that was fitted with a water pump and hydraulic jet dredge constructed with a dredge bar 46 cm wide, with 11 water jets aiming down into the sediment and 3 water jets aiming back to wash the quahogs into its cage. The boat crew consisted of a captain and two deckhands. The captain steered the boat and raised and lowered the dredge by pulling ropes, one to a clutch and one to a brake, on the left side of the wheelhouse. The deckhands emptied the dredge and culled the quahogs on a table next to the rail in the center of the deck.

The boat began dredging at 7:54 a.m., and subsequently towed the dredge in 3 tight circles, <300 m in diameter, before lifting it for emptying. If towed

Figure 27. — Boat, which uses hydraulic escalator harvester, at dock, West Sayville, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 28. — Picking quahogs from "trash" moving along conveyor belt on hydraulic escalator dredge boat, Great South Bay, N.Y. Fisherman tosses the quahogs into hand sorters on the far side of the belt, 1998. Photograph by C. L. MacKenzie, Jr.

Figure 29. — Emptying quahogs from hand sorter on hydraulic escalator harvesting boat, Great South Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

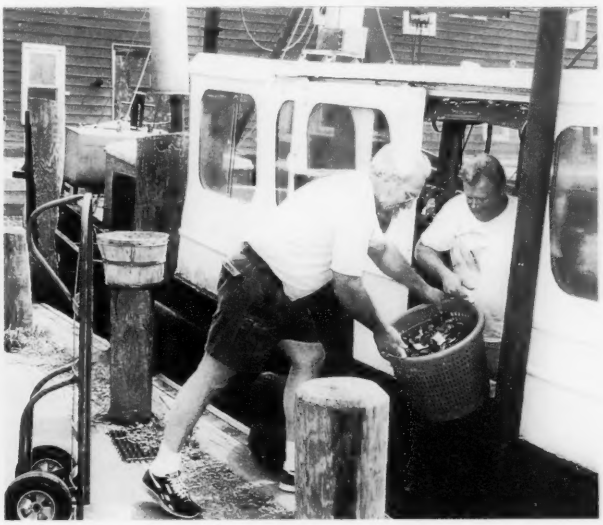

Figure 30. — Removing harvest of quahogs from hydraulic escalator harvesting boat, Great South Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

in a straight line, the water hose from the deck pump to the dredge could be cut by the propeller. Most tows lasted about 7 min. Each time the dredge was lifted to the surface (Fig. 33), the captain dipped it up and down in the water about seven times to wash out mud and sand and then brought it up and swung it over the culling table. A deckhand emptied its contents by releasing a door on its bottom (Fig. 34) and then swung the door closed, the dredge went back over the side, dropped

Figure 31. — Quahog raker on public ground(foreground), and quahog dredging boat on private lease (background, at left), Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 32. — Quahog harvesting boat with deckhands culling quahogs while boat is dredging, Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 33. — Hydraulic quahog dredge emerging from water after 7-min tow, Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 34. — Emptying quahogs from hydraulic dredge onto culling table, Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 35. — Culling quahogs on harvesting boat, Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 36. — Lifting hopperful of quahogs from boat onto dock, Oyster Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 37. — New York and New Jersey locations mentioned in text.

Figure 38. — Raking quahogs in Raritan Bay, 1860's (Harper's Weekly, 1869).

into the water, and then to the bottom. Standing on opposite sides of the table, the 2 deckhands rapidly picked out the quahogs from the shells present, tossed them into half-bushel baskets, and pushed the shells off the end of the table and they dropped overboard (Fig. 35). When filled, the baskets of quahogs were emptied into three 25-bushel hoppers. The time lapse from first lifting the dredge until it went back overboard was 1 min.

By 2:30 p.m., the harvesting was finished. The dredge had been lifted and emptied 35 times, harvesting 62 bu of quahogs. We returned to the dock in the town of Oyster Bay, and the nearly full hoppers were lifted onto the dock by crane and run into a cold-storage room (Fig. 36). The next day, the quahogs would be culled into four marketing sizes by machine, bagged, and then trucked to restaurants in New York City.

The F. M. Flower Co. has a hatchery in Bayville on the northwest side of Oyster Bay that is capable of producing 50–60 million quahog seed and 50–60 million oyster seed/yr. The seed initially is grown on rafts anchored about 75 m from the hatchery in quiet waters until the quahogs attain a length of about 10 mm and the oyster seed are 25–30 mm long, and then they are planted in beds that are a few meters under water. The company removes predators from the beds with suction dredges before planting the seed but does not place screens over it. When crabs are abundant, they can kill many seed, and so the company removes most of them with traps to keep their losses low.

Raritan Bay, N.Y. and N.J.

Before the 1860's, quahogs most likely were harvested at wading depths around the shores of Raritan Bay (Fig. 37) by treading and with short rakes. In the mid 1860's, George Eldridge, inventor of the bull rake, used this new rake out of a rowboat to gather virgin quahog stocks in the deeper bay waters. Other fishermen soon made similar rakes and eventually a fleet of boats with fishermen using bull rakes was harvesting quahogs in the bay (Leonard, 1923) (Fig. 38).

Harvesting with bull rakes involved jerking the rake through the bottom, about 50–100 mm at a time. In doing so, fishermen could feel and hear the quahogs collecting and rattling in their rakes. "It's the kind of music we like to hear," one fisherman remarked in the 1880's (Kobbe, 1982). After pulling the rakes through the bottom for about 1.8 m, the fishermen pulled them up to remove the quahogs.

Wind and water currents were important to hand raking. Fishermen harvested the most quahogs, i.e. 6–12 bu in 5–6 hr of raking each day, when the wind and current were in the same direction. When the wind and waves were opposed, the boats remained almost stationary and the fishermen had to push the boats away from the rakes and could jerk them only 8–12 times before having to push again. The result was fewer quahogs. The Raritan Bay bottoms where the New Jersey diggers rake have entirely mud-like sediments. The fishermen have explored digging in areas where the bottom is hard sand, but found harvests poor there.

The first description of sail dredging in Raritan Bay was included in an 1875 letter to Ernest Ingersoll (1887: 597–598): "They go after hard-shelled clams from Keyport (New Jersey) in squatty, one-sailed boats, called "cats" (catboats) dragging clam-rakes, which are thrown out and drawn by the wind. The ground extends in Raritan Bay from Sandy Hook to South Amboy (A distance of 20 km). A good day's catch was from 3 to 3.5 barrels (9–10 bu). The man who owns his boat and sells stock by the ten or twenty thousand at wholesale is sort of an aristocrat compared to those (diggers of softshell clams) who go down to the shore daily, with a basket, get their somewhat precarious catch, take it home on their backs, open the bivalves, and then peddle the result in a can with a quart measure in the other hand."

From 1915 to 1925, the earliest period for which data are available, about 40 boats comprised the sail dredging fleet, and in the late 1920's and the 1930's the fleet size was 25–30 boats. At times, when the weather was too bad for local lobstermen to venture into the ocean to lift their pots, a few joined the regular quahog harvesting fleet by adding temporary sails to their skiffs and putting on dredges.

At low wind speeds, sloops could tow only 2 dredges; if more were towed, the boat would stop or move too slowly. As the wind picked up, the men added a third dredge and finally a fourth. A typical drift was 1.5–3 km long and lasted about 1 hr, depending on the size of the quahog bed and wind speed. As the boat drifted, it pitched and rolled, pulling the rakes slowly and then quickly through the bottom, keeping the mud-like sediments passing through. It was common for the boats to move too slowly to dredge on summer mornings, when the wind was too light, or when the wind and current were in opposite directions. When conditions were good, daily catches ranged from 15 to 30 bu for 2-man boats, and was about 10 bu for one-man boats.

During most of the 1800's and into the early 1900's, this fishery alternated by season with the oyster and blue crab fisheries. The same boats were used for harvesting quahogs during warm months (April through August), oysters during the fall and early winter (September through December), and blue crabs during the rest of the winter (January through March). The oyster industry ended for good during the early 1920's, and from then on the boats harvested quahogs into October and then converted to dredging for blue crabs.

During the 1920's, quahoging was depressed in Raritan Bay. New York authorities had banned harvesting quahogs in its waters, which comprise the northern half of the bay, due to pollution. At that time, about 12 men were bull raking on the New Jersey side of the bay. During the 1930's, the situation changed dramatically because seed quahogs had set densely over vast areas of the bay in 1930 or 1931. The fishermen found the set, and they learned they could sell the seed for $1.00–$1.50 a bushel to leaseholders in Barnegat and Chincoteague Bays for planting, growth, and later harvest. To collect the seed, fishermen inserted screen mesh in their bull rakes; each could then harvest several bushels of seed per day. From 500 to 600 men, mostly raking from row boats, became involved in the fishery, each earning as much as $10 on good days. When the quahogs reached about 1 inch (25.4 mm) long, another market developed, when truckers who had delivered coal to the local area from Pennsylvania, purchased them. They carried the quahogs back to Pennsylvania towns and sold them to be eaten raw on the half-shell or steamed (*Red Bank Register*, 1935).

In the early to mid 1930's, when the quahogs attained littleneck and cherrystone sizes, authorities in New York temporarily banned the importation of Raritan Bay quahogs for public health reasons. However, in 1935 the U.S. Health Service certified the New Jersey beds as safe for quahog harvest, and on 15 October 1935, New York City lifted its ban on New Jersey quahogs. In 1939, authorities opened some beds in the New York half of Raritan Bay for quahog harvesting (Fig. 39). The landings of marketable quahogs from the bay rose from 11,560 bu (worth $13,029) in 1933 to 141,167 bu (worth $164,930) in 1938 (MacKenzie, 1992a).

During the 1940's and 1950's, each bull raker was harvesting 8–10 bu of cherrystone and chowder quahogs a day in New Jersey beds. However, as many as 50 New Jersey quahogers went across the state line in Raritan Bay to harvest quahogs illegally in New York waters. They dug at night to avoid detection because the New York residency laws restricted harvesting to state residents. Each New Jersey quahoger often harvested as many as 15–20 bu/night, thus explaining their willingness to risk incarceration to gain access to the New York resource (MacKenzie, 1992a).

From 1946 to 1961, in the New Jersey portion of Raritan Bay, about 20 boats harvested quahogs with rocking-chair dredges. The beds were in deep water, 6–8 m, which were not being exploited by the rakers. Each boat had a captain and two deckhands. Crews towed their dredges for about 10 min before retrieving and emptying them. Each tow collected 2.5–4 bu of cherrystones and chowders. The deckhands usually worked steadily, picking quahogs off the decks and bagging them. Each boat harvested about 40 bu of quahogs per trip. Dredging operations were confined to November through February because at other times the dredging forced sediment into the quahogs that were open and pumping water and this reduced their marketability. This dredge fishery in Raritan Bay continued through 1961, when New Jersey temporarily banned all

quahoging in the bay because of pollution (MacKenzie, 1992a).

Available figures on quahog production from Raritan Bay are intermittent. In the late 1870's, annual production of quahogs from the bay was estimated at 150,000 bu (Ingersoll, 1887). In 1897, quahog landings from Richmond County, N.Y., (mostly Raritan Bay) were about 12,000 bu, and, in 1898, 10,000 bu (Townsend, 1901). From 1897 to 1938, quahog landings from Monmouth County, N.J., (mostly Raritan Bay) ranged from 6,026 to 141,167 bu (Townsend, 1901; Fiedler, 1940). From 1885 to 1940, landed prices of quahogs ranged from about $1.10 to $1.50/bu. Before the late 1930's, New Jersey hand rakers temporarily stored their daily catches of quahogs in floating wooden cars in Keyport Harbor and Port Monmouth-Belford. Every week or so, they shipped the quahogs on freight boats, market sloops, and passenger-freight ferries to New York City markets. The sail dredgers sold their quahogs to market sloops which sailed from New York City to Raritan Bay about twice a week (Ingersoll, 1887). Transfers of quahogs from the dredging sloops to the market sloops took place in the bay and they continued into the late 1930's; after that trucks took over the transport.

Before World War II, there were not any contamination problems with quahogs in the New Jersey half of Raritan Bay. But in 1942 and thereafter, areas of the bay were closed to quahoging because the waters had high bacterial counts. In June 1961, the entire bay was closed to harvesting when some people contracted infectious hepatitis from eating quahogs taken from the bay. For brief periods in the 1960's and early 1970's, New Jersey authorities opened Sandy Hook Bay to harvesting for the direct marketing of quahogs, but only a few part-time sail-dredging boats and 10–15 hand rakers were harvesting quahogs. Sandy Hook Bay remained open until 1974, but the entire bay has been closed to the direct harvesting of quahogs ever since. Sail dredging for quahogs which had lasted for about a century ended with this closure (MacKenzie, 1992a).

Figure 39. — Unloading harvest of quahogs at Great Kills, Staten Island, N.Y., 1939. Photograph by A. Lanza. Courtesy of Staten Island Historical Society, Richmondtown Restoration, Staten Island, N.Y.

The quahog beds off Staten Island and in the eastern part of the bay were reopened for harvesting when plants for depurating quahogs were constructed. The first plant began operating in Great Kills Harbor, Staten Island, in 1979. Each day, about 20 men dug quahogs in an area extending south of Great Kills Harbor to Prince's Bay to sell to the plant. In December 1983, the plant closed because it was unprofitable, and quahoging ended in New York waters for the time being.

Fishermen did not harvest any quahogs in the New Jersey waters of the bay from 1974 until 1983, when a quahog depuration plant began operations in Highlands, N.J. State authorities restricted quahog harvesting areas to the southeastern part of Raritan Bay and the Navesink River, where the waters were the least polluted. The two sections below describe how the States of New York and New Jersey restored the quahog fisheries in polluted Raritan Bay.

The New York Side of Raritan Bay

In 1989 the New York Department of Environmental Conservation developed a plan to allow bull rakers to harvest quahogs from the New York waters of Raritan Bay and have them depurated by relaying them to certified waters on Long Island. The harvesting season has since been open from about 20 April to 10 October each year, the precise dates being dependent upon water temperatures, which must exceed 10°C for the quahogs to properly depurate in natural waters. Private companies truck the quahogs to certified waters in eastern Long Island, such as Peconic Bay, where they are held for at least 21 days before being reharvested and sold. The diggers can work from Monday through Friday. Most live on Long Island, where they used to harvest mostly in Great South Bay until the quahogs became scarce there in the last two decades.

On typical days in 1998, 70–80 New York quahoging boats were present on Raritan Bay. Each had a digger and an additional man, termed a "roper," who pulled up the filled rake with a rope and then culled and bagged the quahogs (Fig. 40). Pulling up a full rake is the most tiresome aspect of harvesting quahogs with a bull rake. By hiring ropers, diggers can rake longer hours and the older men (ages from 50 to 70) can rake

a full day. State regulations require each boat must have a culling grate with 1-inch (25.4-mm) openings attached to its side and positioned to ensure the seed fall overboard rather than into the boat as the quahogs are culled. This ensures that no seed is taken from the bay. To keep their boats moving with the tidal current while raking, especially when the wind blows in the opposite direction from the current, the diggers place a "tide sheet" made of plastic in the water so the current will have more drag on their boat (Fig. 41). This contrasts with New Jersey diggers who usually hoist a sail under such conditions while some use tide sheets. In 2001, the sails used lasted 6 months and were bright blue. The diggers usually began raking about sunrise and continued until about 1 p.m. In 1989, 80 boats landed 55,639 bu of quahogs, while by 1998 a similar number harvested 76,000 bu, the highest total ever (Barnes[25]).

The water depth where most diggers rake is about 3.7–4.6 m, but it ranges from 2.4 to 9 m. The bottoms where they rake is almost entirely mud-like sediments or this sediment mixed with sand and most contain considerable quantities of shells of oysters and softshell clams, *M. arenaria*.

New York authorities maintain rigid control over the harvesting. The two critical violations would be: 1) landing quahogs and selling them directly to customers before they are depurated and 2) harvesting in grossly polluted waters (class IV) in far western Raritan Bay. The diggers have to be on the water in discrete crews or groups of no more than 9 boats, with the boats in each remaining within 300 yards of one another. Each crew is under the watch of a crew chief who helps to ensure no quahogs are landed outside of the program. Each crew also has with them a "monitor" (Fig. 42), i.e. a person hired by a private company to remain on the crew chief's boat all day to guard against violations. Since about 80 boats were harvesting daily in 1998, 9 monitors were on the bay watching them. Overseeing all the boats is a crew of two state employees aboard the state boat *Alosa* (Fig. 43). This crew determines which fishermen are digging each day, ensures all the rules are followed, and, when the diggers return to their ports to unload, they go ashore with them to make sure the monitors watch that all bags of quahogs are loaded onto state-approved trucks.

While harvesting, each digger rakes for 3–4 min to fill his rake, and then the "roper" pulls it up as the digger guides the handle. After washing out the mud-like sediment and sand by pushing the rake back and forth a few times in the surface water, the digger empties the quahogs into a basket and then returns the rake to the bottom to resume digging. The "roper" meanwhile empties the basket onto the culling grate and picks out the legal-sized quahogs and puts them in baskets by size. In this program, "littlenecks" comprise littlenecks and topnecks, and "cherrystones" comprise cherrystones and chowders. By state regulation, the quahogs have to be packed in green onion sacks and have a red tag on them which states "for cleansing only."

The rakers harvest the most quahogs when the wind and current move in the same direction, because then the boats drift consistently away from the pull of the rakes. On such days, each digger harvests about 8 bu of "littlenecks" and 6 bu of "cherrystones." When the current and wind are in opposite directions, the diggers have to push their boats away from the rakes and their harvests are from 50 to 66% as large. In 1998, the diggers received $65/bu for "littlenecks" and $10/bu for "cherrystones." The diggers pay their "ropers" $10/bu for "littlenecks" and $1/bu for "cherrystones." On good days, each digger may gross almost $600. After paying the roper, this leaves him with about $500 a day before other expenses are taken out. The many diggers who live on Long Island, about 100–125 km away, have high expenses. Besides the ownership and upkeep of their boat and engine and a dockage fee, most live in nearby motels 4 nights a week and eat in restaurants, while the others who travel back and forth to Long Island every day have high transportation costs.

At the end of a harvesting day, the boats in each crew must return to their ports together. The bags of quahogs are loaded into refrigerated trucks, while their drivers, who are bonded, keep track of the number of bags of each size grouping from each digger (Fig. 44). At around 2 p.m., when the trucks are full (about 300 bags), their rear doors are closed, locked, and then sealed (Fig. 45). The truckers afterward drive for about 3 hr to their homes at locations about mid way on Long Island and park the trucks overnight. The following morning, they drive to the sites where the quahogs will be unloaded and placed in certified waters. Most quahogs are placed in trays, while some are spread on the bottom. The truckers then drive back to Staten Island, arriving by 1 p.m. to pick up that day's harvest of quahogs.

This program, which had a landed value to the diggers of about $2.75 million in 1997, has been profitable for all concerned — the diggers, ropers, truckers, and buyers — and there is little temptation to violate the rules to increase incomes. All participants involved want everyone else to follow the rules so the state will not close the program.

During the off-season, October–April, many diggers, i.e. the "gypsies of the bay," harvest quahogs in other locations. Many trailer their boats and gear to the north shore of Long Island to harvest quahogs in Oyster Bay, Huntington Bay, or Port Jefferson Harbor. If a town controlling a section of Great South Bay opens a previously uncertified section of bottom for winter digging, some go there to harvest. Others dig in New Jersey waters and sell their quahogs to the depuration plants. Still others have trailered their boats to Florida to harvest quahogs in the Indian River Lagoon.

The New Jersey Side of Raritan Bay

In 1983, after urging by the fishermen, the State of New Jersey established a system for some diggers to relay their quahogs to certified leased beds in Barnegat Bay for depuration. The fishermen each gathered 5–8 bu of quahogs a day to relay to their leases. They had to land their quahogs at a marina in Sea Bright by noon each day, put them in the cab

[25]Barnes, D. New York State Department of Environmental Conservation, East Setauket. Personal commun., 1999.

Figure 40. — Raking quahogs in Raritan Bay, N.Y. In foreground, the "roper" is hauling up rake while the raker guides the handle. Photograph by C. L. MacKenzie, Jr.

Figure 41. — Tide sheet used to pull quahog boat away from rake, Raritan Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

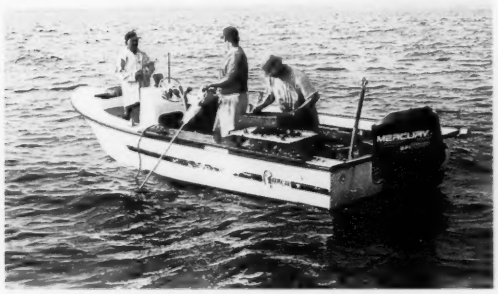

Figure 42. — Quahog raking boat, Raritan Bay, N.Y. State monitor is at bow, raker is in middle, and "roper" is near the stern, 1998. Photograph by C. L. MacKenzie, Jr.

Figure 43. — State of New York boat *Alosa* and crew which oversees quahog harvesting in Raritan Bay, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 44. — Loading quahogs from harvesting boat onto truck, Tottenville, N.Y., 1998. Photograph by C. L. MacKenzie, Jr.

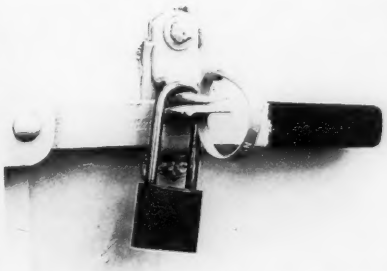

Figure 45. — Lock and seal on the cab of a truck used to relay quahogs from Sea Bright, N.J., to Barnegat Bay shore, 1998. Photograph by C. L. MacKenzie, Jr.

Figure 46. — Fishermen in Raritan Bay, N.J. aim their rake handles high into the air as they retrieve their rakes from the bottom, 1998. Photograph by C. L. MacKenzie, Jr.

Figure 47. — When rake is near water surface, the fishermen lower the cross-bar and styrofoam float at the end of the handle to the water. Photograph by C. L. MacKenzie, Jr.

(covered cargo bed) of their truck that was locked and then sealed by a state conservation officer, then travel to Barnegat Bay and arrive there by about 2 p.m. In Barnegat Bay, each digger had three 0.5-acre leases on which to depurate the quahogs. At the Barnegat Bay shore, a conservation officer removed the seals and then watched the diggers plant the quahogs on appropriate leases. The quahogs had to remain on the leases for at least 30 days at temperatures at least as high as 10°C before they could be marketed.

The water depth over most Barnegat Bay leases is about 2 meters. The diggers have boats and rakes in Barnegat Bay similar to those in Raritan Bay, except that the rake handles are about 3.7 m long. About 1 day a week, during the months when water temperatures are above 10°C, instead of harvesting in Raritan Bay, each harvests about 30 bu of quahogs from his lease. A few diggers spread their quahogs on tarpaulins in 60–90 cm of water and harvest them with toothless tongs.

In 1990, about 15 New Jersey "relayers" were raking daily in southeastern Raritan Bay. Quahog abundance was limited to small areas and the fishermen attempted to hide any small concentrations they had found from one another. But during the 1990's, the abundance of market-sized quahogs erupted over hundreds of acres in all soft bottoms. Similarly to the situation in Connecticut at the same time, the starfish population which had been abundant during the early 1980's had crashed (MacKenzie and Pikanowski, 2000).

A large increase in quahog fishermen and landings followed. By 1991 the number of rakers had increased to 30, all of whom were relayers. In 1992, a depuration plant with a daily capacity of 120 bu opened in Sea Bright, N.J., and, in 1995, a second depuration plant with a daily capacity of 240 bu opened in Highlands, N.J. State authorities allowed the plants to operate under the condition that television cameras monitor the tanks 24 hours a day so State of New Jersey personnel in offices in its Nacote Creek Field Station and in the main office in Trenton could monitor water temperatures, oxygen concentrations, and flow rates, and watch for violations such as short depuration times. Both plants have run at full capacity. By 1999, the number of diggers who were harvesting during every good-weather day had increased to about 100; 60 sold their quahogs to the 2 depuration plants, while 30–40 relayed their quahogs to Barnegat Bay (Harry[26]).

Since the capacity of the 2 plants is a total of 360 bu of quahogs/day, each fisherman selling to them has been put on a limit of 4–8 bu/day; the number of bushels/man depended on the number of fishermen who arrived to dig each morning. The relayers can land an unlimited quantity each day. The plants sort the diggers' quahogs by size and pay them according to the quantity of each size they harvest. The diggers who sell to the plants and some relayers harvest quahogs year-round. The relayers who plant quahogs on their leases during the winter cannot harvest from them until the following April and May when water temperatures have risen rise above 10°C for 30 days.

The depuration plants sell their quahogs to outlets in New Jersey and nearby states. During the warm months, about 66% are sold wholesale to fish markets in states as far away as Ohio, and the remainder are sold retail to nearly 500 restaurants within the New Jersey area. In the winter, more quahogs are sold wholesale in New York City than to the summer outlets (Harry[26]).

The 30–40 relay fishermen (Fig. 46, 47) in New Jersey land their quahogs at the site of the depuration plant operated by Brooks Seafood in Sea Bright and truck them to Barnegat Bay each day, where they spread them on their leases.

[26]Harry, J. Relay quahog fisherman, Raritan Bay and Barnegat Bay, New Jersey, and President of the New Jersey clam relayers. Personal commun., 1999.

The relayers have a slight monetary advantage over those who sell to the depuration plants because they obtain full market prices for their quahogs (usually about $0.20 for each littleneck) whereas those who sell to the depuration plants were paid less ($0.14 for each littleneck) in 1998. Each fisherman usually harvests about 4–7 bu for a total of about 90–150 bu/day by the relayers 1998. A typical relayer harvests quahogs about 100–110 days/yr in Raritan Bay, whereas a typical fisherman who sells to the depuration plants harvests about 200 days/yr in Raritan Bay. The State of New Jersey and the plants allow the diggers more days to rake, but strong winds, an occasional engine breakdown, harvesting from relay leases nearly once a week, and personal business, including visits to doctors, reduces the number of days they can harvest. The relayers can harvest from sunup until 1 p.m. on Mondays through Fridays, while the diggers who sell to the plants can harvest from sunup until 4 p.m. on Mondays through Saturdays.

The diggers toss back most of the chowders they rake because they can sell them for only about $3/bu, but they retain the littlenecks, topnecks, and cherrystones to gain as much money as they can. They believe returning the chowders maintains an adequate spawning stock in the bay. The state allows a maximum of 3% of their catch to be undersized quahogs; a 1-in (25.4 mm) width is the minimum size allowed. The program is tightly controlled by the state and has been running well with no problems of contaminated quahogs getting to market. State wardens watch the diggers from the shore to ensure they do not land and sell quahogs anywhere but at the sites of the depuration plants.

The diggers have various types of expenses. One is a dockage fee of $1,200/yr for their boats. Another is a $75 annual state harvest license. The diggers are charged $5 for each bushel they land: $2 pays for the State of New Jersey law enforcement team, $1 for the diggers' lawyer, $1 for dues in their association, and $1 for workers to carry the quahogs from the shore a distance of about 45 m to the plant. The relayers are charged only $4/bu because they put the quahogs on their trucks themselves. Additional costs to the diggers include engine fuel and upkeep of equipment. It costs $400 to obtain a lease in Barnegat Bay and have it surveyed, and $5/yr for lease renewals.

Trip on a Quahog Raking Boat: Raritan Bay, N.J., 11 August 1998

The fisherman, a relayer, 57 years old, docked his boat in a slip at a dock belonging to Brooks Seafood about 60 m from Hwy 36 in Sea Bright, N.J. About 30 other quahog raking boats were also moored there. The depuration plant was situated between the dock and the highway. On this day, the fisherman raked in the southeastern part of Raritan Bay in a bed where the water depth was 7.5 meters. Diggers have difficulty working there when the current and wind are in opposite directions, because the rake consistently goes underneath the boat no matter on which side of it they rake. Using their sail (Fig. 48) does not help unless the wind is unusually strong, so the diggers may move to beds farther west where conditions will be better. The current, by itself, can pose a problem if it runs for an hour or so in one direction along the bottom and in the opposite direction near the surface. It messes up the rake handle and makes raking difficult.

The equipment on this fisherman's boat consisted of a stainless steel suitcase rake that was 70 cm wide with teeth 7.6 cm long, four 3.65-m sections of handle to be used with the rake, a 2-layered sorting box in the center of the boat near the bow, a winch on the port rail next to his raking position, and a blue plastic sail on the starboard side. The winch was turned by a 1-hp electric motor powered by a battery, whose power lasted 2 days. The digger had 2 batteries, one in use and the other being charged at home to be switched with this one every second day. In 7.5 m of water, he used all 4 sections of handle to make a 14-m handle (Fig. 49). The state allows the diggers to hoist their rakes by power. A 6-mm diameter nylon line was attached to the rake (Fig. 50), and when the digger wanted to lift it, he ran the end of the line around the winch and stepped on a floor pedal and then the rake full of quahogs and soft sediment rose to the surface in about 30 seconds as he guided the handle.

His sorting box measured 75 × 90 cm (Fig. 51). Its upper grate had spaces wide enough to allow seed, littlenecks, and topnecks to fall through, withholding cherrystones and chowders. Its lower grate with 1-in (25.4-mm) spaces held the littlenecks and topnecks, letting the seed fall through. The two grates were hinged at opposite ends of the box. The digger emptied his rakefull of quahogs onto the upper grate, shook it, and then lifted its left side so the larger quahogs would fall off into a basket or onto the deck of the boat. He later discarded them overboard. He then shook the lower grate and the seed fell through into a basket and the seed was also discarded overboard. He then lifted the right side and the littlenecks and topnecks fell through a funnel into a burlap bag resting on the deck.

The digger usually harvested 4–7 bu of littlenecks and topnecks/day, or about 22 bu/week. On this summer day we left the dock at 6:30 a.m., and he began raking at 6:50 a.m. and finished at 9:02 a.m. During one typical raking, he jerked (pulled) the rake 60 times before retrieving it. He said he usually jerks it about 50 times when the quahogs are abundant and as many as 150 times when they are scarce before retrieving it. He made 38 rakings. His harvest was 5 bu comprising about 2,250 littlenecks and topnecks, or an average of about 59 keeper quahogs/raking.

At the shore (Fig. 52), he put his bags of quahogs in the cab of his truck, locked the cab and it was sealed by a state law enforcement officer. For the next 2–4 hr, he and the other 15–20 relayers got together in groups of 4–6 individuals, and stood by or sat in their trucks or on a bench, relaxing and talking together about the day's conditions for raking, good periods of harvesting in the past, how many more years harvesting quahogs will last in the bay, and they criticized and made fun of one another's methods and gear. They appeared to relish this period of sharing observations every day, which contrasted with the hours of solitude they spent driving from home to Sea Bright, raking, and then driving alone for 50 min to a site on the shore of Barnegat Bay, and then home again. At 1 p.m., a train of 12 fishermens'

Figure 48. — Pushing boat away from rake in light wind. The sail is only partially effective in doing this in such a wind, Raritan Bay, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 49. — Typical raking position of quahog fisherman in Raritan Bay, N.J. Note Styrofoam float on rake handle and rope and hauler used to retrieve the rake. Photograph by C. L. MacKenzie, Jr.

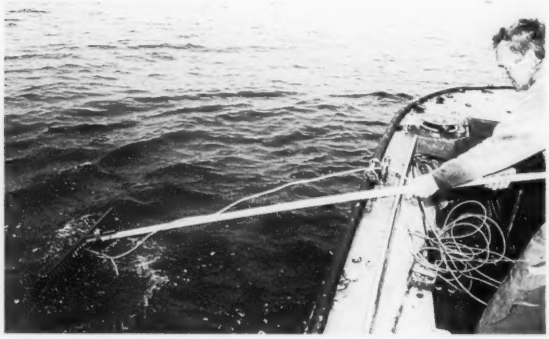

Figure 50. — Raker washing his quahog catch before dumping them onto his culling table (sorting box), in Raritan Bay, N.J., 1998. Note rope and hauler used to bring rake to surface. Photograph by C. L. MacKenzie, Jr.

Figure 51. — Rakeful of salable quahogs on sorting box of raking boat after upper grate, at right, was lifted and chowders slid off onto the floor, Raritan Bay, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 52. — Raritan Bay quahoger with his daily catch, Sea Bright, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

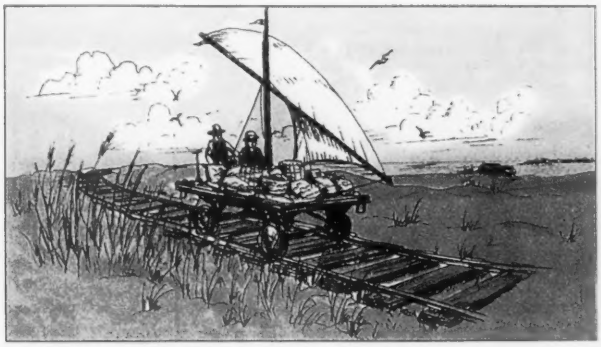

Figure 53. — Fishermen in Tuckerton, N.J., rigged an abandoned railroad flatcar with a mast and "sailed" their quahogs and fish on an abandoned spur from docks at the shore to the main rail line in the town in 1892. This sailcar was operated on the rail spur until 1915. When there was no wind, the fishermen pulled it or used a horse to pull it. It was eventually wrecked by teenage pranksters on a Halloween night. Original pen and ink illustration by Sheila Mickle Kierce, *Asbury Park Press* newspaper.

Figure 54. — Peddler with cart for selling quahogs and fish, Barnegat, N.J., 1920's (from Sim, 1949).

pickup trucks left the parking lot and then followed the state law-enforcement vehicle for the drive to Barnegat Bay. Once there, the state officer removed the seals from the cabs and the fishermen put the quahogs in their boats, drove to their leases, and spent 10 min spreading the quahogs over them.

The fisherman had 125,000 littlenecks and topnecks on his lease. When prices were around $0.20 for each quahog he sold some, but when they dropped to $0.15 to 0.17 each or less, he left them on the lease. They were like money in the bank. In contrast, the fishermen who sold to the depuration plants had to accept what the plants were paying for quahogs each day they harvested.

New Jersey's Coastal Bays and Delaware Bay

Quahogs grow in the three largest coastal bays (Barnegat Bay, Little Egg Harbor, and Great Bay), small coastal bays to their south, and lower Delaware Bay in New Jersey (Kennish et al., 1984; McCloy and Joseph, 1985; Joseph, 1989) (Fig. 37). The first reference to quahog harvests in the coastal bays was by Smith (1690), who said, "We have a store of clams (quahogs), esteemed much better than oysters; on festivals the Indians feast with them; there are shallops (scallops), but in no great plenty." The second such reference was by Barber and Howe (1844), who described people supplying quahogs to soldiers fighting in the American Revolution in the 1770's: "The aged people in (Cape May County in Dennis Township) can recollect that in the dark days of the Revolution when the army was barefoot and provisions were extremely scarce their people boiled out, dried, and strung large quantities of clams and transported them to the army. No doubt, they were esteemed as a luxury by the half-starved soldiers."

Ingersoll (1887) estimated quahog production from the coastal bays was about 240,000 bu in 1880. The quahogs bought the fishermen $0.60/bu. Quahog production from the entire state, including Raritan Bay, peaked at nearly 600,000 bu in 1900, it declined and fell to its lowest historical ebb in the mid 1920's (Fig. 53, 54), but rose afterward. Many of the quahogs landed in the 1930's and 1940's were chowders that were sold to canning companies. State production afterward rose unevenly into the mid 1950's. By the late 1950's, the canning companies purchased surfclams instead of quahogs and the demand for the chowders fell substantially (Ford, 1997).

During the 1950's, about 250 fishermen were harvesting quahogs in Barnegat Bay during the summer (Jenks[27]); many were high school and college students (Chadwick[28]). Most fishermen used tongs and short rakes for harvesting, while some used bull rakes and some treaded (Jenks[27]). After the 1950's, quahog abundance declined in the coastal bays, especially in Barnegat Bay and Little Egg Harbor.

McCay and Jenks (1997) described an exceptional heavy set on the Goose Bar in Little Egg Harbor that occurred in 1972. Local fishermen harvested the seed, which they termed "buttons," with rakes, put some on their leases, and sold the remainder to other leaseholders. One leaseholder was able to plant 350,000 "buttons" on each of 2 leases. The quahogs became a financial bonanza for him and several other leaseholders when they sold them as littlenecks 2 years later.

By the early 1990's, during the spring and autumn, about 45 commercial fishermen were digging quahogs, while in the summer the daily number rose to 130. In 1990, the average daily harvest for full-time fishermen was 900 quahogs.

[27]Jenks, W. III. Retired shellfisherman, 134 South Beverly Drive, Brick, New Jersey. Personal commun., 1998.

[28]Chadwick, J. Quahog fisherman, Barnegat, New Jersey. Personal commun., 1998.

Most were harvested with bull rakes, while some were taken by treading (Ford, 1997). The numbers of commercial fishermen continued to decline and, by 1998, only about 14 were digging quahogs during the spring and autumn, while about 30 (8 in Barnegat Bay, 12–18 in Great Bay; 7–8 in Little Bay) were digging in the summer. The diggers saw little seed in the beds (Lauer[29]).

During the late 1990's, the meats of some quahogs in Barnegat Bay and Little Egg Harbor were dark gray: The mantles, gills, and soft parts of the quahog bodies, but not the foot, were so colored, and they become darker when cooked. Besides, the meats were thinner than normal quahogs. The occurrence of the "black" quahogs was spotty. In one bed, nearly all the quahogs were black, while in another nearly all quahogs were normal. Littlenecks had the least blackness, while cherries and chowders had the most (Lauer[29]). One local dealer (Lauer[30]) estimated perhaps 10% of the quahogs in the two bays were "black." In 1998 and 1999, the "black" in the meats had spread southward to Great Bay also. The condition slowed quahog sales (Lauer[29]).

In the 1980's and 1990's, hatchery production of quahogs in the coastal bays developed successfully. In the 1990's, 7 hatcheries were operating, and an estimated 33% of the quahog harvest from New Jersey waters came from their seed (Ford, 1997). Each year, the largest hatchery has raised 20–50 million seed quahogs and sells them to the growers, while another hatchery has raised 10–20 million seed quahogs and produces 200,000–300,000 littlenecks from the seed it raised. In 1990's, however, brown tides, caused by *A. anophagefferens*, were reducing their anticipated production by preventing growth of the quahogs during blooms (Bates, 1999), and there was a threat of the meats becoming "black" in Hammock Cove (Harry[26]).

About 50 former and part-time quahog harvesters and some coastal residents obtained leases, each around 2 acres in size, from the state to grow the hatchery seed to littleneck size and then market them. Nearly all the leases are located in Hammock Cove, locally called "Dry Bay." The cove, which is nearly 1 km long, and located about 1.2 km south of Great Bay, is shallow and goes nearly bare at low tide. At low tide, most leases are in thigh to waist-deep water. During such tides, the growers can spread their seed quahogs and then lay screens over them for protection against blue crab predation. The screens collect biotic growth which has to be manually scrubbed off by the growers about once a week during the warm months and less frequently during the winter or the quahogs will suffocate and die. The scrubbing is the only maintenance the quahog plantings require except for killing an occasional blue crab that gets under a screen, but the scrubbing is rather laborious (Fenton, 2001).

In the early 1990's, Hammock Cove was only partially planted with quahogs, and they grew to market size in 1.5 to 2 years. By 2001, the bay has been entirely planted with them and, consequently, the quahogs grow more slowly: It now requires 3 to 4 years for a quahog to grow to market size. This has placed an extra burden on the growers because they have to clean their screens for 3 to 4 years to obtain a quahog crop. The growers recently have been "making a living" by working their leases, but do not make any money beyond that (Fenton, 2001).

New Jersey's coastal bays support a large recreational quahog fishery. In 1996, 7,558 recreational licenses were issued. The recreational fishermen can legally harvest as many as 150 quahogs/day for their personal use. Most harvest at wading depths using short rakes. This fishery accounted for about 20% of the total quahog harvest from the bays (Ford, 1997).

In lower Delaware Bay, quahogs at times are harvested with oyster dredges constructed with extra long teeth. The only statistics available on landings from the bay are for the period from 1941 to 1965. A total of 470,000 bu, or an average of about 20,000 bu/yr, were harvested (Ford, 1997).

Trip on a Quahog Raking Boat: Barnegat Bay, 15 October 1998

A trip was taken with a 70-year-old bull raker in Barnegat Bay opposite the town of Barnegat near the southern end of the bay. His wooden boat, 6.7 m long, had a 235-hp automobile engine that was 14 years old. He had a plastic sail aboard to help move the boat when he raked on the days with little wind. He harvested quahogs with a 22-tooth bubble rake that had a 6.7-m handle. The locations of the beds in which he harvests were all about 2 m deep.

The mainland to the west of the bay is flat and low. To the east is Long Beach Island, a low, narrow strip of land between the bay and the Atlantic Ocean. No hills can be seen when one looks shoreward in either direction from the water. Since the early 1960's, a great many summer homes and condominiums have been built and now on both coasts they cover about 80% of the bay's shorelines, much of which has been bulkheaded. The only relatively pristine shores are two wildlife refuges and Island Beach State Park which is along the east side of the bay.

Except for 2 years in the armed services, 1943–45, the digger had harvested quahogs nearly year-round in the bay for 60 consecutive years beginning when he was 10 years old. During his first 2–3 summers, he bull raked alongside his father in their boat; his father retrieved and emptied his rake after he filled it. His face was weathered and his arms and hands were thin and sinewy (Fig. 55).

He related the following observations about quahoging in the bay:

1) Quahogs burrow more deeply and catches decline if fishermen rake a bed for several days. Leave it alone for 2–3 weeks and they come up again. The harder the bottom, the "touchier" it is. Sand bottom is really "touchy." The small quahogs go down first. Years ago, when a fisherman started in a bed, if he harvested 2,000 necks and 600 big quahogs a day, after a week or so he'd get 1,000 necks and 600 big ones a day.

2) Quahogs also burrow deeply in hot weather. They come up in the fall and go deeper again in the winter.

[29]Lauer, R. Quahog dealer, Barnegat, New Jersey. Personal commun. 1999.

[30]Lauer, P. Shellfish Dealer, Barnegat, New Jersey. Personal commun., 1999.

3) It's difficult harvesting in the bay during windy periods, because the surrounding land is so low. Years ago, one could dig near a shoreline, but now the state has closed all those nearshore areas during the warm months due to pollution. Winter harvesting is difficult because it is windier more often.

4) In 1972, he and his brother took 350,000 seed from the Goose Bar and planted them on a public bottom, intending to harvest them when they grew to littleneck size. But 2 years later, when they had become littlenecks, he was ill for part of the year, and other fishermen harvested the littlenecks by treading, leaving none for him.

5) From the 1960's to the mid 1970's, Barnegat Bay had 40–50 regular quahogers; in the 1960's, they got from $0.025 to $0.03 for each quahog. Each harvested 2,000–2,500 quahogs of all sizes each day and seed appeared plentiful. Whenever the harvesting was really good, he got as many as 1,000 quahogs/hr.

In recent days, the digger's harvests have diminished because the quahogs have moved deeper into the sediments as the water has become cooler. In the summer of 1998, he harvested an average of about 150 quahogs/hr, but in the fall and winter he harvests about 100 quahogs/hr. During a year, he sees only small quantities of seed in the bay.

Two weeks ago, he tried raking quahogs at an experimental site established 2.5 km east of his dock, by the National Marine Fisheries Service and Rutgers University. Broken surfclam shells had been spread over plots in two concentrations: 300 bu/acre and 1,000 bu/acre. Quahog setting has since been light, but the more heavily shelled plots had 6 times more quahogs than the unshelled control plots. The fisherman said the shells were too abundant to allow harvesting of quahogs with bull rakes. The quahogs could be harvested some day with tongs that cover less area. In using tongs, fishermen would drop the shells back in place and they would continue to have their enhancing effect.

The previous day (October 14), he had found a productive location and harvested 500 littlenecks and cherrystones, far above his usual catches. He and four other quahog diggers tie their boats at the same docking site, and they know the quantities each other harvests each day. This raker did not want the other four to find his good spot, and so he had to go to a different location this day.

We left the dock at 8:10 a.m. (Fig. 56) and arrived at a raking spot 2 km from his dock at 8:20 a.m. The bottom was hard muddy-sand. The wind was blowing at 15–18 kn from the northwest, and so he put out a weight that dragged along the bottom to slow the movement of the boat. The air temperature was in the 40's.

The bay was lonely at this time of year. When we arrived, no other quahogers were in sight. But during summer days in the 1990's, dozens of sail and motor boats could be seen whenever a quahoger glanced around.

Several minutes after he began raking, the digger glanced toward the western shore and said, "Look, here they come." Three other diggers were coming toward us, hoping it was his good spot. They came close and raked around us but found the harvests relatively poor and they left after about 20 min. The digger was able to keep his good location known to himself for another day.

He moved his rake with rapid jerks (pulls), each probably moving his rake about 25 mm through the bottom. He raked for 3–5 min each time before pulling up the rake. In one typical raking, he jerked the rake 380 times before retrieving it (far more times than fishermen jerked their rakes between lifts in other bays where sediments are softer) (Fig. 57). He picked the quahogs from the rake by hand, because he caught too few to empty it onto his sorting grate (Fig. 58).

The digger quit working at 9:00 a.m. because the cold wind now was blowing over 20 kn and his fingers had become stiff and they ached. He had made 7 rakings and had only 47 quahogs (range, 2–11/raking). He did not collect any seed in his rake. This harvest was too small to sell to the dealer whose shop was 50 steps from his dock (Fig. 59). Instead, his wife will make a pie with them: chopped quahog meats, diced potato, onion, and bay leaves and salt for taste under a crust.

The digger believes his harvests will increase after 1 November, when state authorities will open some grounds close to shore for harvesting. The state closes them from 1 April to 31 October each year when the waters have high bacterial counts. The diggers get their highest catches in those areas in March when the quahogs come up near the surface of the sediments.

Maryland

In Maryland, quahogs are harvested commercially in its coastal bays (Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay, Newport Bay, and Chincoteague Bay) and in Tangier Sound within Chesapeake Bay (Fig. 60). The state's regulations for quahogs are as follows: The open season runs from mid September to the end of May, the maximum number of quahogs a boat can land in a day is 8,000, and the minimum quahog width is $^{7}/_{8}$ in (22 mm).

In the coastal bays, the highest quahog densities are present in shell-sand substrates; lower densities are found in sand substrates (Boynton, 1970; Homer[31]). Between 1940 and 1968, commercial catches ranged between 60,000 and 250,000 lb of meat (7,500 and 31,250 bu)/yr. During the mid 1950's, fishermen were allowed to use bull rakes, and, in 1967, hydraulic escalator dredges were introduced. In recent decades, though, quahogs have been harvested only by escalator harvesters (Fig. 61). In the 1968–69 season, state quahog harvesting totaled 3,505 boat-days, and, of these, 1,157 boat-days had the maximum allowable catch of 8,000 quahogs. The twenty most active hydraulic dredges had their maximum allowable catches about 60% of the time (Boynton, 1970). From then until the early 1970's, between 40 and 50 boats harvested quahogs in the coastal bays, but in 1975, only 2 escalator harvesters operated in the bay; after that, the number increased to 6–12 escalator harvesters and in 1998 there were 22 escalator harvesters (Homer[31]).

The annual harvest of the industry is somewhat limited by bad weather, when

[31]Homer, M. Fisheries Division, Maryland Department of Natural Resources, Solomons. Personal commun., 1999.

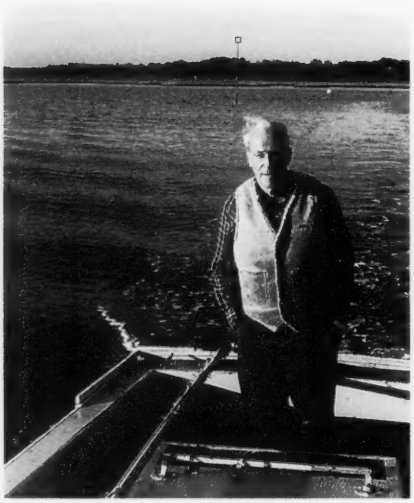

Figure 55. — In 1998, this fisherman had raked quahogs year-round in Barnegat Bay, N.J., for nearly 60 years. Photograph by C. L. MacKenzie, Jr.

Figure 56. — A type of docking facility for quahogers in Barnegat Bay, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 57. — Raking quahogs in Barnegat Bay, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 58. — In recent years, quahogs have been scarce in Barnegat Bay, N.J., 1998. Photograph by C. L. MacKenzie, Jr.

Figure 59. — Small-scale buyer sorting quahogs in Barnegat, N.J., 1998. Note shipping tags on wall at right. Photograph by C. L. MacKenzie, Jr.

fishermen cannot operate their hydraulic escalator rigs. A record of harvesting days for January, 1970, revealed the fishermen were able to operate their rigs for only 4–5 days. In the early fall and spring, good weather conditions permitted more activity, usually amounting to 3–4 good quahoging days a week (Boynton, 1970).

In 1994 and 1995, the coastal bays had large quahog sets, predacious blue crabs afterward were relatively scarce, and the result was a mini-boom in quahog landings. In 1998, the harvesters each landed a full limit of quahogs/day during the first 3 months of the season though later catches fell. Maryland quahog landings that year were worth nearly $1 million, the highest since the early 1970's. Recreationalists harvest quahogs in the coastal bays using short rakes (Homer[31]).

In Tangier Sound, 8–12 boats harvest quahogs with patent tongs because by law hydraulic escalator dredges are excluded from oyster bars in Chesapeake Bay. Fishermen find the quahogs primarily around the edges of oyster bars. Each boat usually lands 4,000–5,000 quahogs/day and sells them for an average of $0.08–0.09 each (Homer[31]).

Virginia

Virginia's quahogs grow in the lower (high salinity) sections of Chesapeake Bay's tributary rivers and in bays on the eastern shore (Fig. 60). In the 1950's and 1960's, about 33% of the state's quahogs were produced in the bay, while the eastern shore produced about 66% (Castagna and Haven, 1972). In Chesapeake Bay, quahogs once were harvested with short rakes at wading depths and with patent tongs in deeper waters. Short raking is no longer practiced because the quahogs are scarce in shallow waters, but patent tonging continues as the only harvesting method employed. Some boats are fitted with Loran plotters to help fishermen relocate the densest beds (MacKenzie, 1997b). The quahogs from Hampton Roads, a polluted area, have been sold to shellfish dealers who have depurated them in large floats or directly on the bottom.

During the 1950's and 1960's, buyers usually sent a truck to pick up quahog

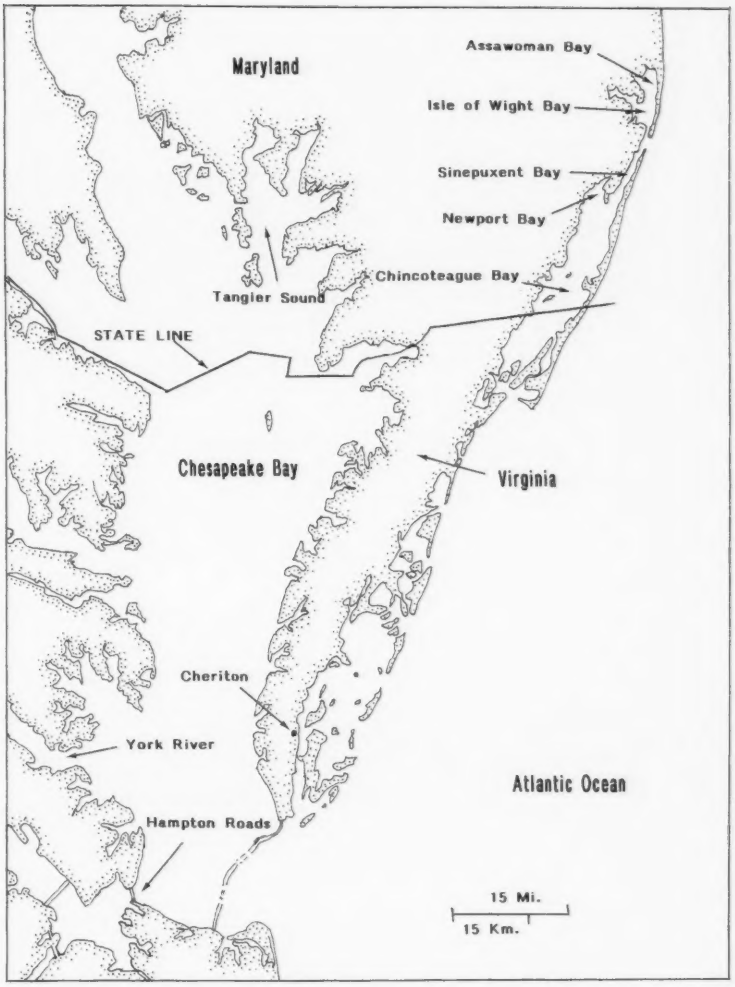

Figure 60. — Section of coastlines of Maryland and Virginia showing locations mentioned in text.

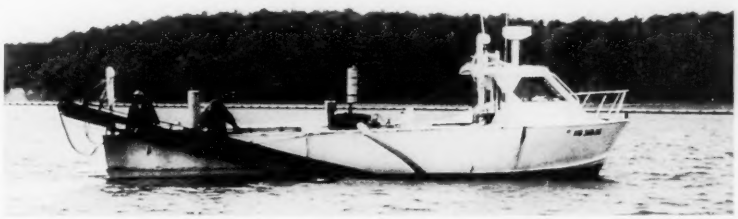

Figure 61. — Harvesting quahogs using hydraulic escalator harvester, Chincoteague Bay, Md., 1990's. Photograph by M. Homer.

landings once a day throughout most of the year. They did not compete with each other and prices did not vary much between buyers. If necessary, the buyers stored the quahogs temporarily in a cool, dark room. Their shipping trucks often were cooled with ice but seldom refrigerated. During the same period, one successful entrepreneur on the eastern shore purchased quahogs from fishermen in the warm months and held some until winter, when prices for quahogs rose because few were being harvested in New York, Rhode Island, and Massachusetts. He had them stored on intertidal flats or in floats, and later gathered them from the flats with quahog rakes, sawed off potato rakes, and picks, and from the floats with shovels (Castagna and Haven, 1972). The fishermen in those northern states had shifted from quahoging to harvesting bay scallops, a higher priced crop than quahogs, from September into December and sometimes later depending on the size of the scallop crop. In addition, bays in those states were subjected to wind storms or froze over briefly during December, January, and February, making quahoging impossible. The Virginia entrepreneur sold about 30,000 bu of quahogs/month (Fig. 62, 63, 64, 65). The J. H. West Company on the eastern shore currently continues this practice of selling quahogs during the winter and sells 6–7 million quahogs (15,000–20,000 bu)/yr (West[32]).

Patent tongers continue to harvest quahogs in certified and restricted waters, the latter for depuration. In 1999, about 100 boats using patent tongs were harvesting quahogs in the entire state. Most of the fleet was harvesting them in uncertified waters, during an open season that ran from 1 May to 15 August. The fleet was concentrated in Hampton Roads where about 70 boats worked nearly 8 hr/day, 5 days/week during good weather. Each double-rigged boat (using 2 patent tongs, 1 on each side) harvested about 5,000 littlenecks and 400 cherrystones/day and each single-rigged boat harvested about half that total. The fishermen returned the chowders to the beds. They received $0.12/littleneck if harvested in uncertified waters and $0.17/littleneck if harvested in certified waters. Fishermen bagged the quahogs, took them to a state-designated landing site, put them onto trucks whose cabs were then locked and sealed by Virginia Marine Resources Commission officers, and then the quahogs were taken to various certified waters for replanting. They were placed in submerged trays with covers (Fig. 66) that were locked shut and then sealed by a state officer, or planted on sections of bottom marked with yellow flags. The quahogs had to remain in the clean waters for at least 15 days of depuration. Conservation officers afterward removed the seals of the cages and the quahogs could be marketed (West[32]).

Haven et al. (1975) stated relayed quahogs were not able to withstand environmental stress such as low salinities, as well as quahogs native to the areas. In one instance, water runoff from a tropical storm led to from 33 to 100% mortalities in tray and bottom-planted quahogs, while mortality in native quahogs was 5%.

In eastern shore bays, fishermen harvest most quahogs by treading and using short rakes at wading depths, or by digging with 2-tine picks on bare flats. From 100 to 125 treaders and diggers harvest quahogs year-round, each harvesting 250–1,000 quahogs/day. In addition, 2 boats are rigged with patent tongs for harvesting quahogs in channels (MacKenzie, 1997b).

The eastern shore has some large quahog hatchery-growout farms; the farms are located on the ocean side and bay side of the peninsula. Quahog larvae are reared in five hatcheries. The seed is grown first in screen-covered trays and then in intertidal flats or shallow waters with screens covering them. The hatcheries grow some of the seed to market size themselves, and they have agreements with other leaseholders who take the seed from the hatcheries, grow them to market size, sell them, and then share the profits about 50:50 with the hatcheries. About 150 people work in the hatcheries and on the farms. In 1997, they produced about 75 million market-sized quahogs (75,000–100,000 bu) (West[32]). Since then, the quahog farms have been growing somewhat in number and production.

North Carolina

North Carolina (Fig. 67) was the leading quahog producer in the South Atlantic region until Florida surpassed it in the 1990's. Quahog landings have been reported in North Carolina since 1880 (Chestnut, 1953). From before 1900 until 1978, total annual production averaged between 250,000 and 350,000 lb of meats (30,000–40,000 bu). But between 1979 and the mid 1980's landings increased to an annual average of around 1,125,000 lb of meats (135,000 bu). Production had increased because the demand for quahogs increased and mechanized equipment was introduced for harvesting them (Rhodes et al., 1977; Guthrie and Lewis, 1982). A decline afterward is attributed to a decrease in the size of the mechanical harvesting fleet and the closure of many harvesting areas due to a red tide in 1988.

Annual landings values of quahogs since 1990 have ranged from $3.6 million to $6.5 million and average $4.7 million. The prices fishermen have received for quahogs has risen during the past few decades, ranging from $0.01/quahog in 1971 to as much as $0.18 for littlenecks and $0.08 for cherrystones and $0.08 for chowders during the mid 1990's (Taylor, 1995). A study of the North Carolina quahog market showed consumers' disposable incomes rather than the sizes of landings was the more important factor in determining the dockside value of quahogs (Hsiao et al., 1986).

The quahogs have been harvested from high-salinity areas just inside the barrier islands from Ocracoke southward to the South Carolina border, a 285-km stretch. In addition, beginning in 1960, about 12 shrimp trawlers using rocking-chair dredges harvested southern quahogs in 9–12 m of water in the Atlantic Ocean between Cape Lookout and Beaufort Inlet, North Carolina. That fishery continued through 1962 when the resource became scarce (Porter and Chestnut, 1962).

The State's minimum legal size limit for quahogs is 1 in (25.4 mm) thick

[32]West, J. H. J. H. West Company. Eastern Shore, Virginia. Personal commun., 1999.

Figure 62. — Gathering quahogs on a holding lease, Chincoteague, Va., 1948. From A. Aubrey Bodine collection, courtesy of The Mariners' Museum, Newport News, Va.

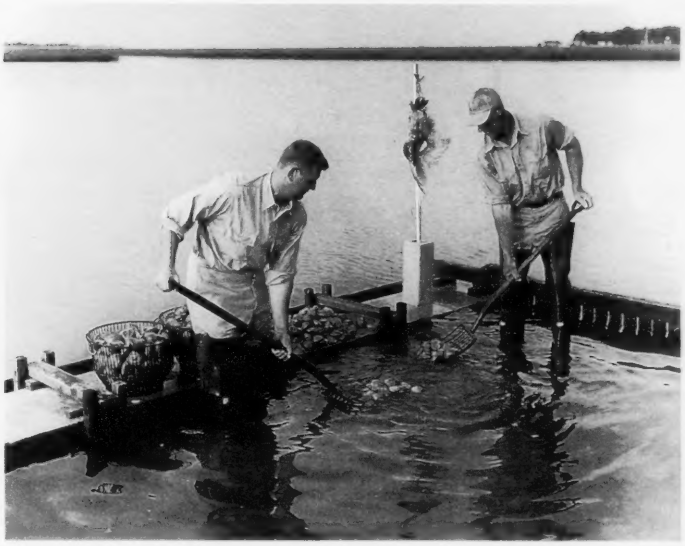

Figure 63. — Removing quahogs from a float, Chincoteague, Va., 1948. From A. Aubrey Bodine collection, courtesy of The Mariners' Museum, Newport News, Va.

Figure 64. — Packing quahogs for sale, Chincoteague, Va., 1948. From A. Aubrey Bodine collection, courtesy of The Mariners' Museum, Newport News, Va.

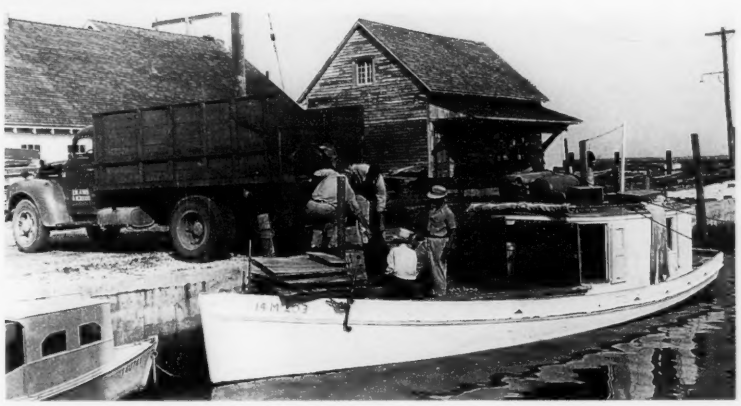

Figure 65. — Loading quahogs onto a truck bound for northern markets, Chincoteague, Va., 1948. From A. Aubrey Bodine collection, courtesy of The Mariners' Museum, Newport News, Va.

Figure 66. — Trays for holding quahogs for depuration, Menchville, Va., 1995. Photograph by C. L. MacKenzie, Jr.

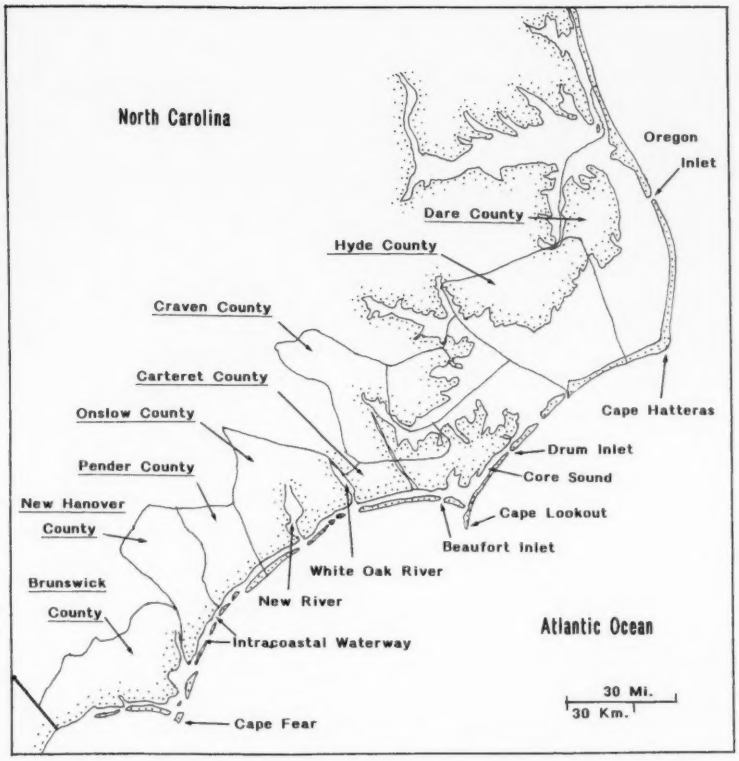

Figure 67. — Coastline and counties in North Carolina with locations mentioned in text.

with the exception of quahogs from aquaculture or hatchery operations, which can be marketed at any size. The daily maximum harvest limit is 6,250 quahogs (about 12–20 bu depending on size) per fishing operation, while the noncommercial harvest limit for people without a commercial shellfish license is 100 quahogs/person/day, not to exceed 200 quahogs/boat/day. It is unlawful to take quahogs by any method other than using hand tongs, hand rakes, or hands in any bed of live oysters, or in any bed of submerged aquatic vegetation. There are no seasonal restrictions for hand harvesters; harvesting is allowed year-round. In recent decades, the Division of Marine Fisheries sold 7,198 shellfishing licenses in 1976, 15,709 in 1982, and 7,910 in 1993. This license allows a fisherman to harvest commercial quantities of oysters, quahogs, and bay scallops. The state has not tallied the numbers of active quahogers during typical days in any season. In addition, about 157 fishermen hold leases for planting and harvesting oysters and quahogs.

Many fishermen harvest quahogs nearly full-time and make a living using hand gear: tongs, bull rakes, short rakes, and "pea diggers." Some of the others are retirees, students, and people with other jobs who harvest quahogs to supplement their incomes. The mechanical quahog harvesters are opportunistic, adaptive fishermen who go shrimping and crab potting in the summer and go beach seining for mullet, quahoging, and bay scalloping in the fall and winter. About 80% of quahog landings are from Carteret County, with the remainder from Onslow and Pender Counties (Taylor, 1995).

In the mid 1990's, the gross annual income from quahoging for those who did not have a lease was nearly $2,200, while the income of those who had a lease was almost $8,200. The average gross income/quahoger averaged $2,366 (range, $145–$48,366). The more income fishermen receive from quahoging, the less they are dependent on other fisheries. Those without leases derive about 26% of their total fishing income from quahoging, while leaseholders are far more dependent, receiving 70% of their total fishing income from them (Taylor, 1995). Hsiao et al. (1986) estimated the total annual operating costs for North Carolina boats using hand gear at $808, for those using hydraulic dredges at $2,080, and for the kickers at $3,000 in 1967 dollars.

Fishermen harvest quahogs by hand (treading) and with short (hand) rakes at wading depths, and with hand tongs and bull rakes in deeper waters. The treaders (stompers) wear sheets of rubber tire tubes or neoprene booties on their feet while harvesting. Besides finding quahogs with their feet, treaders sometimes get on all fours and search through the bottom sediments for quahogs with their hands. Hand harvesting is done year-round, but is most active from spring through fall when water temperatures are comfortable.

Hand raking was the only type of harvesting with tools practiced before the

Figure 68. — Using pea diggers to harvest quahogs in shelly intertidal bed, Carteret County, N.C. Photograph by North Carolina Department of Environment and Natural Resources, Morehead City.

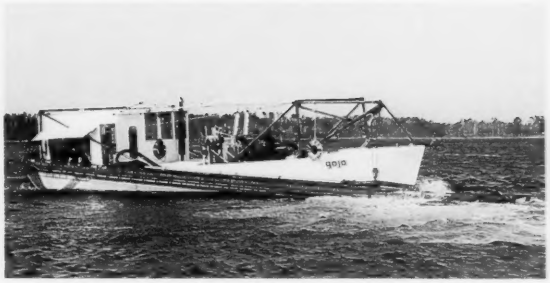

Figure 69. — Hydraulic escalator dredge for quahogs attached to boat. Anterior end has been raised to water surface (State of North Carolina). Photograph by C. L. MacKenzie, Jr.

mid 1940's. The hand rakes include "pea diggers" (Fig. 68) and lightweight aluminum-handled models with stainless-steel tines. In the mid 1970's, New England and New York fishermen introduced bull rakes to North Carolina fishermen, and they have since used them to harvest quahogs in the deeper waters of the Intracoastal Waterway that extends along coastal North Carolina. Each hand raker harvests about 700 quahogs/day, while each bull raker harvests about 1,100 quahogs/day.

The two mechanical harvesting gears employed are the kick boat and the hydraulic escalator dredge boat (Fig. 69). Towed dredges and patent tongs currently are not being used. In 1970 about 30 boats were involved in quahog kicking, during the 1986–87 mechanical harvest season 350 mechanical kicking and dredging permits were issued, but by 1998–99 the number declined to 144 permits. The number of permits issued, however, is a somewhat misleading indicator of effort. As examples, during the 1988–89 season, 348 kick boats were issued permits to operate, but the highest daily number actually working was 174 (on the second day of the season); and in the 1992–93 season, aerial surveys counted a high of 65 boats working on one day, although 174 permits had been issued. The number of hydraulic escalator dredgers working has fallen from 22 in the mid 1980's to 10 in 1999.

In areas where quahogs are relatively scarce in shallow waters, kicking is the only practical method for harvesting them because the boats cover much bottom. In 1998, each kick boat harvested about 6–8 bags/day (250 quahogs/bag) at the beginning of the season and 4–5 bags by mid season. Quahog abundances in the kicking areas have declined over the years (Taylor, 1995).

From 1979 to 1993, hand harvesters landed about 70% of total quahog production. But in 1994, mechanical harvesting surpassed hand harvesting with a production of over 700,000 lb of meats (82,000 bu), or 54% of the total.

Conflicts have arisen over the limited quahog resources being sought by more harvesters and consisted of user allocation effects and perceived adverse environmental effects. During the early 1990's, allocation conflicts arose when hand harvesters and mechanical harvesters worked in the same areas. Hand quahogers blamed the stock declines on the mechanical harvesters. They believe the mechanical harvesting causes destruction of 1) the quahog habitat, 2) the young quahogs by burying them, and 3) the grass beds. They also object to the trenches left by mechanical tools. The Division of Marine Fisheries was tasked with mediating the disputes and trying to allocate productive bottoms among the hand and mechanical harvesters.

In the late 1980's and early 1990's, as areas became increasingly depleted of quahogs, or as seagrass beds spread naturally and put areas out of bounds, the mechanical harvesters demanded that the state open more harvesting areas to them. Existing rules prohibit the opening of any areas other than those that have been opened since January 1977. Criteria have not been formally adopted for opening areas, but bottom type, depth, presence of vegetation, historical use, and social considerations are evaluated in the decision. Few additional areas have been opened and the conflict of a decade ago has largely subsided. The other broad category of conflict concerns the real and imagined environmental effects of mechanical harvesting, which does degrade beds of vegetation and oysters (Peterson et al., 1987). This is why sensitive areas are off limits to mechanical harvesting.

Hatchery production (Fig. 70, 71) is not yet important in North Carolina, in part because people feel one group should not have control over a bottom that would otherwise be used for harvesting by rakers. North Carolina has six quahog hatcheries. They rear some of their own seed and sell some to fishermen who grow it on their leases. The state allows leasing of some bottoms that have less than 2 quahogs/m^2.

Nearly all quahogs landed in North Carolina are sold through licensed wholesale dealers. In fiscal year 1994–95,

81 dealers handled the North Carolina quahog harvest. Of these, 23 were from Carteret County, 20 from Brunswick County, 14 from New Hanover County, 12 from Onslow County, 7 from Pender County, while 4 were from Craven, Hyde, and Dare Counties combined. The dealers grade the quahogs by size, pack them in burlap bags, and ship most to northern markets such as Baltimore, Philadelphia, New York, and Boston (Taylor, 1995).

Many fishermen are critical of the state's failure to enhance the depleted quahog resources. They suggest a state-operated hatchery producing seed quahogs or a relaying of polluted stocks to public bottoms would help the situation. Using large hatchery seed quahogs (14–22 mm), a late fall planting time to avoid some predation, a sparse planting density of 1 quahog/m^2, and choosing shelly bottoms in traditionally productive areas may provide a feasible means of stocking quahogs on public bottoms (Peterson et al., 1995; Taylor, 1995).

Pollution, based on coliform bacteria counts, has closed 48,480 acres out of North Carolina's 813,000 acres of quahog bottoms to harvesting. The closures are in areas with the most human population growth. Domestic pollution (treated municipal sewage, septic tanks, marinas, and nonpoint agricultural pollution run-off) accounts for nearly all such closures. Some of the state's richest shellfish beds have been affected, a trend that will probably continue as the human population and coastline development increase (Taylor, 1995).

In November 1987, the first documented red tide in coastal North Carolina forced the closure of 99% of the state's quahoging areas. The red tide devastated the industry. The tide persisted for about 3 months and shellfishermen collectively lost millions of dollars in income. Red tides are caused by blooms of a single-celled phytoplankton *Ptychodiscus breve* (Tester et al., 1988). Quahog landings for 1987 were 1.2 million lb of meats (144,000 bu), but dropped to 925,000 lb of meats (109,000 bu) in 1988 (Taylor, 1995).

During each spring, private leaseholders relay quahogs from polluted waters to their leases for later harvest. The polluted areas from which relaying is allowed are regulated by the U.S. Food and Drug Administration and by the North Carolina State-controlled Shellfish Sanitation Section. The Division of Marine Fisheries' enforcement group oversees the harvest and guards the leases while quahog depuration occurs. The Marine Patrol guards the leases which contain the contaminated quahogs for at least a 2-week purging period. The quahog concentrations make a tempting target for poachers (Taylor, 1995).

Recreational quahog harvests are not reported, and the size of the recreational fishery is unknown. Many recreational fishermen also harvest quahogs commercially part-time, using hand methods in shallow waters.

Figure 70. — A quahog and oyster hatchery, Harkers Island, N.C., 1999. Photograph by C. L. MacKenzie, Jr.

Figure 71. — Tubs with screen bottoms for growing seed quahogs, Harkers Island, N.C., 1999. Photograph by C. L. MacKenzie, Jr.

South Carolina

Most of the quahog fishery in South Carolina (Fig. 72) is based on wild stocks, and it now is the most valuable molluscan fishery in South Carolina, having supplanted the oyster fishery in 1982 (Low[33]). Before 1973, all quahogs were taken by hand harvesters using bull rakes, various other rakes, tongs, or seed forks, and from time to time, by small box dredges pulled behind power boats (Ashley[34]; Carson[35]; Keith[36]). From 1974 to 1980 mechanical harvests dominated landings. Increased landings in the 1970's generated a market for quahogs, and this encouraged more hand harvesters to enter the fishery; they now are responsible for most of the production. Currently, Charleston County leads in quahog landings, owing to the concentration of aquaculture activities in and around Folly Beach and the wild harvest in the McClellanville area. The wildstock landings in pounds of meats (bushels) were 351,920 (40,000) in Charleston County; 35,836 (4,000) in Beaufort County; 15,272 (1,745) in Georgetown County; and none in Horry County in 1998 (Low[33]).

Quahogs were used by aboriginal tribes for food and the shells for tools

[33]Low, R. A. Marine Resources Division, South Carolina Natural Resources Department, Charleston. Personal commun., 1998.

[34]Ashley, E. Owner, Ashley Seafood, McClellanville, South Carolina. Personal commun., 1998.

[35]Carson, W. Z. Head, Marine Licensing Office, South Carolina Natural Resources Department, Charleston. Personal commun., 1998.

[36]Keith, W. J. Shellfish Management Section, South Carolina Natural Resources Department, Charleston. Personal commun. 1998.

and trade items as early as 4,000 years ago (Burrell, 1997). While not addressing specific shellfish species, laws addressing waterway pollution were in place in South Carolina as early as 1726 (Heaton, 1972). Quahog landings were small when first reported in 1880. South Carolina's major commercial fishery from the 1800's until after World War II centered on the eastern oyster (Lunz, 1944, 1949, 1963). But in 1902, buyers from North Carolina created a demand for quahogs and landings soon exceeded 225,000 lb of meats (26,000 bu). The next year landings fell again and remained below 100,000 lb (11,000 bu)/yr until 1958, but landings probably were under-reported because an organized market was not in place. Hugh McGinn[37], an early resident of Little River, S.C., recalls several buyers around the area shipping quahogs to Wilmington, N.C., on the converted purse seiner *Prince* in the early 1920's. He said this boat brought freight back to Little River, but had it not had the income from transporting the quahogs north this would not have been a profitable venture.

In the early 1920's, North Carolina buyers competed with a local buyer at Little River and a conflict between the parties led to the pursuit of a legislative solution. Possibly as a result of this, the South Carolina legislature in 1924 outlawed out-of-state shipments of quahog shell stock, restricted harvests to state residents, and outlawed the use of dredges in less than 12 ft (3.7 m) of water (Coastal Fisheries Act, 1924). This led to an almost complete lack of reported harvests until the restriction of shipping out-of-state was removed in 1959 (Coastal Fisheries Laws, 1959; Lunz, 1960). Before World War II, the quahog fishery was plied almost exclusively in Horry and Georgetown Counties, the two northernmost counties in the state (S.C. State Board of Fisheries, 1926, 1934). This fishery was closed in one or both counties for several years and this further decreased reported production (S.C. State Board of Fisheries, 1927, 1931).

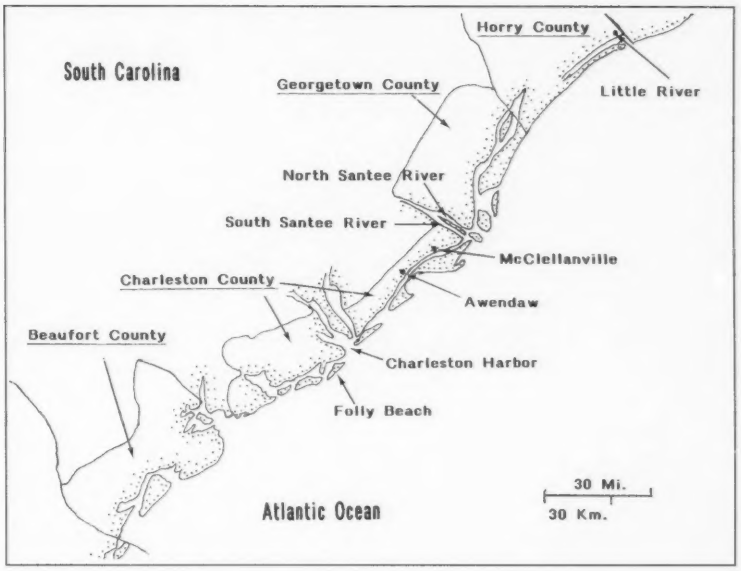

Figure 72. — Coastline of South Carolina showing locations mentioned in text.

Once quahogs were again permitted to be shipped out of state in the shell, interest in harvesting picked up, but until the early 1970's landings remained low. In 1972, the South Carolina Wildlife and Marine Resources Department (SCWMRD), now the South Carolina Natural Resources Department (SCNRD), began a survey of the state's quahog resources (Anderson et al., 1978). This survey identified dense beds of quahogs in the lower Santee River. The beds were in three fairly distinct locations: North Santee Bay, North Santee River, and South Santee River. The beds were opened to harvesting by boats using hydraulic escalator dredges in 1973 (Gracy et al., 1978). From 4 to 10 boats harvested from the beds for 15 years under SCWMRD permits (Haven et al., 1979; MacPhail, 1961).

Fishermen were allowed to harvest 2 days/week during a season, which lasted 2–5 months usually beginning in January and ending in April (Anderson and Keith, undated). Beds were surveyed each year before the season using an escalator harvester dredge to estimate the quantity of quahogs present. With this information, in 1978, the SCWMRD began to restrict harvests to 1–2 beds each year, permitting stocks in the closed areas to rebuild (Rhodes et al., 1977). The most efficient operators landed around 20 bags/hr at the beginning of a season, but this dropped to less than 3 bags/hr by the end of the season. The bags contained about 250 ungraded quahogs (Gracy et al., 1978; SCWMRD, 1980; Low, 1998). In 1982 a little over 500,000 lb in meat weight (57,000 bu) valued at about $1,000,000 were landed in the state (SCWMRD, 1984).

Drainage from the Santee watershed was diverted to Charleston Harbor in 1942 but was rediverted back into the lower Santee channel to relieve silt accumulations in Charleston Harbor in 1985 (SCWMRD, 1986). Two dry years allowed the Santee quahog fishery to continue, but freshwater intrusions followed and the beds were closed to direct harvest in 1988, thus ending a well-managed and productive fishery (SCWMRD, 1988). Over 37 million quahogs (nearly 100,000 bu) had been harvested from the beds in those years.

The peak number of hydraulic escalator dredges used in South Carolina was 10 in the mid 1970's. Hurricane Hugo destroyed several dredges, and 4–6 now

[37]McGinn, H. T. 4410 Mineola Ave., Little River, South Carolina. Personal commun., 1998.

remain in use in restricted areas for harvesting quahogs to be depurated on leased bottoms, and to transplant seed oysters and shell to leased areas (Ashley[34]; Keith[36]; Anderson[38]; Baldwin[39]).

Restricted shellfish areas periodically are opened by the SCNRD and by the South Carolina Department of Health and Environmental Control (DHEC) to harvest quahogs for depuration. Crews using hydraulic escalator dredges usually do the harvesting. In previous years, quahogs were processed in five coastal depuration plants supervised by the DHEC and harvesting by both the DHEC and SCNRD. The plants used ultraviolet-treated water, and the quahogs had to be submerged for least 48 hours in a recirculating system; the capacities of the plants ranged from 77 to 153 bu/cycle (Newell[40]). In 1983, the plants closed owing to irregular quahog supplies and poor profits. Since then, quahogs have been relayed by truck to certified beds in Virginia for depuration. The DHEC supervises this operation at the shipping point and Virginia Health officials control it at the receiving end (Coker[41]; Leland[42]).

The modern quahog harvest season runs from 15 September to 15 May, but it may be extended or curtailed by the SCNRD or DHEC (SCMRD, 1996). Most South Carolina quahog harvesting occurs after the first of January because nearly all the fishermen are still working on shrimp boats or are involved in the oyster fishery. Some women and children in the Awendaw area pick quahogs in the fall, harvesting them with rakes and forks in the intertidal zone in creeks and along the shore in the intracoastal waterway. Working at low tide, they average around 400 quahogs per day. While most of the quahog harvest is still trucked to northern markets, an increasingly larger quantity is being sold locally (Leland[42]). A state law requires wild-harvest quahogs measure at least 1 inch in thickness, but cultured quahogs may be smaller.

The number of people employed in the South Carolina quahog industry cannot be well estimated. Licensing laws are complicated and records are difficult to interpret. A person quahoging commercially on state shellfish grounds must have a shellfish license, a "land-and-sell" license, a boat license (if used), and a permit for the specific gear used, i.e. rake or tongs. If several members of a family are working together, only one of them is required to have a land-and-sell license. Those working leased beds are required to have only a boat license (if using a boat) and a gear license. Those who work both state and private beds need all licenses. Many shellfishermen land oysters at one time of the year and quahogs at another time, but due to recent oyster die-offs more effort is being put into quahog harvesting. A decline in gear licenses probably reflects reduced participation in the oyster fishery.

Each recreational fisherman must have a state saltwater fishing stamp to gather oysters and quahogs. In 1997, 94,000 stamps were purchased, and, of those holders, 20% were estimated to have gathered oysters or quahogs. Extrapolating from a survey of stamp purchasers, we estimate 30% of the quahog landings are by recreational fishermen (Langely, 1998; Waltz[43]).

A program to determine the feasibility of developing commercially viable methods for quahog culture was begun in 1979 at the South Carolina Marine Resources Research Institute (SCWMRD, 1978). Quahogs were selected as a species to concentrate on because of their hardiness, high value at an early age, a ready market, and availability of growout areas (Burrell, 1977; Manzi et al., 1981). Growth rates and seed survival studies in subtidal and intertidal trays were high enough to promise good results (Eldridge et al., 1976, 1979).

In 1981, a study began to assess the feasibility of intensive aquaculture. One project to select for enhanced growth in quahog broodstock resulted in superior lines which mariculture operators now used as parents of their seed. Geographic crosses and good brood lines are maintained (Dillon and Manzi, 1987, 1988; Hadley et al., 1991; Manzi et al., 1991; Eversole et al., 1996). Another project, which lasted for three years, incorporated a 3-step program: 1) nursery, 2) primary field growout, and 3) secondary growout. Land-based raceways were used to grow seed quahogs (1–6 mm) imported from commercial hatcheries to about 10 millimeters. The seed then were placed in protected trays on leases and grown to 25 millimeters. These were relayed in other trays at lower densities for growout to harvest size. Up-flow nursery systems eventually replaced raceways because they were easier to keep clean, they required less space, and the quahogs were easier to handle (Manzi et al., 1981; SCWMRD, 1982). This program was a cooperative effort involving the S.C. Marine Resources Research Institute, a commercial entity (Trident Sea Farms), and the Sea Grant Program. Although this project did not result in a viable commercial quahog mariculture operation, it did develop the technology to enable quahog mariculture to have a promising future in South Carolina (Hadley et al., 1997).

Florida

Florida's quahog production (Fig. 73) has surged in the past two decades. Before the 1980's, landings from the Indian River Lagoon, in Brevard County, Fla., averaged less than 12,500 bu/yr (Adams, 1988). But beginning in 1981 dense sets of quahogs occurred in the lagoon, survival was good, growth rate was rapid (Jones et al., 1990), and a commercial fishery soon developed. Although Ryther (1988) suggested the sets resulted from above-normal rainfall during 1982–84, it is more likely several years of below-normal rainfall before 1982 provided good salinities for successful quahog recruitment and growth.

[38]Anderson, W. South Carolina Department of Natural Resources, P.O. Box 12559, Charleston. Personal commun., 1998.

[39]Baldwin, R. Shellfish culturist and escalator harvester operator. P. O. Box 262, McClellanville, South Carolina. Personal commun., 1998.

[40]Newell, C. L. South Carolina Department of Health and Environmental Control, 1705 Oak Street Plaza Suite, Myrtle Beach. Personal commun., 1998.

[41]Coker, M. M. Shellfish Supervisor. South Carolina Department of Health and Environmental Control, 1362 McMillan, North Charleston. Personal commun., 1998.

[42]Leland, R. III. Carolina Seafood, P.O. Box 285, McClellanville, SC. Personal commun., 1998.

[43]Waltz, W. South Carolina Department of Natural Resources, P.O. Box 12559, Charleston. Personal commun., 1998.

In response to the increased quahog supply, the number of fishermen increased rapidly, and by 1984 they landed at least 175,000 bu valued at $4.4 million. Those landings represented over 80% of Florida quahog landings (Barile, 1988) and at least 10% of the United States total (Pratt, 1988). The fishery was productive but short-lived. Landings peaked in 1985 at 475,000 bu valued at $8.1 million, but production declined thereafter in response to massive quahog mortalities caused by freshwater flowing into the beds from flood-control canals (Barile and Rathjen, 1986).

The economic success of quahoging in the lagoon attracted fishermen from some northern states, and much of that immigration was solicited by local processors who, eager to exploit this fishery, advertised in northern newspapers to attract experienced quahogers. A daily earnings potential of $300 per person attracted quahogers from Massachusetts, Rhode Island, New York, and North Carolina. Florida did not the have a residency law (as did many northern states), and so nonresident quahogers had free access to the quahogs. Although some quahogers remained in Florida after the fishery collapsed in the late 1980's, most returned home to beds in the northern states (Busby, 1988). However, the northern fishermen left behind the knowledge and technology (mainly modern bull rakes, Fig. 74) for continued Florida quahoging (Barile, 1988). Some Indian River quahogers are using stilts that enable them to walk across the bottom while raking (Fig. 75, 76), thus covering more ground than they otherwise would if restricted to their boat, and many Indian River quahogers have set aside their bull rakes and have begun using scuba or surface-supplied air sources that enable them to work directly on the bottom of the lagoon.

The influx of northern quahogers placed heavy burdens on the Florida Marine Patrol, the enforcement branch of the Florida Department of Environmental Protection. With a limited number of officers to patrol the extensive Indian River Lagoon quahog beds, and with over 1,000 quahogers on the water on any given day, the Marine Patrol had difficulty monitoring open-water quahog operations (Fig. 77) and overseeing quahog relay operations.

Figure 73. — Coastline of Florida showing locations mentioned in text.

The establishment of quahog depuration plants contributed substantially to the expansion and continuation of the Indian River Lagoon quahog fishery. The fishermen could harvest quahogs in uncertified waters after the loss of the large quahog beds in the southern lagoon (due to freshwater inputs) and have them depurated so they could be marketed. The quahogers also became aware of other areas with large quahog resources in the lagoon. The depuration option and additional harvesting grounds in the northern lagoon allowed several hundred quahogers to remain employed in the lagoon through the late 1980's and early 1990's.

During 1990–91, a second major quahog set occurred, this time in the northern part of the river. Harvesting of these quahogs began in 1992 and lasted through 1996, when again low salinities on the beds caused large quahog mortalities followed by substantially smaller landings. During the peak of this fishery, as many as 1,200 licensed fishermen landed about $8 million worth of quahogs. Experience gained during the early 1980's in the southern lagoon minimized both quahoger-quahoger and quahoger-regulator conflicts. In addition, a preexisting license requirement reduced the numbers of immigrant quahogers. But a new conflict arose between wild quahogers and aquaculturists. It was centered on space, as aquaculturists leased and occupied space previously available for open-water quahoging. The development and application of regulations that prohibit aquaculture leases in naturally productive quahog areas has since minimized this conflict.

Scuba picking has become a common harvest method in the Indian River Lagoon, because of year-round warm water and soft sediments. Diving pickers can remain in the water for a few hours

Figure 74. — The narrower rake is used to harvest quahogs in hard bottoms, while the wider rake is used to harvest them in mud bottoms, Indian River Lagoon, Fla., 1997. Photograph by W. S. Arnold.

Figure 76. — Raking quahogs in Florida's Indian River Lagoon while standing on stilts. Cross-head is fastened near middle of handle instead of its end. Photograph by W. S. Arnold.

Figure 75. — Stilts and type of rake fishermen use to harvest quahogs in Indian River Lagoon, Fla. Note position of cross-head. Photograph by W. S. Arnold.

Figure 77. — Raking quahogs in Florida's Indian River Lagoon. Photograph by W. S. Arnold.

a day and rarely need to surface if they use a "surface-supply" air system rather than scuba. As in Narragansett Bay, scuba picking is controversial. The rakers feel scuba pickers take quahogs from them, because they cover larger areas. Since the pickers cannot be easily observed from the surface, they are difficult for wardens to oversee. Divers who harvest quahogs illegally at night are nearly impossible to observe and control, and even during the day it is difficult to monitor the catch because the diver may simply leave the quahogs on the bottom for later retrieval. In the late 1990's, quahogs became scarcer in the Indian River Lagoon. The rakers blamed large harvests by the divers, whose numbers reached about 200, for the decline.

Quahog culture in Florida began in the late 1970's when fishermen in the Indian River Lagoon area began investigating it because their wild quahog harvests fluctuated too widely. But during the 1990's, quahog farming surged in Florida, especially on its west coast. It developed as a means to employ fishermen displaced from oystering and net finfishing. When the Food and Drug Administration closed Suwannee Sound to oyster harvesting due to pollution, the oyster fishermen were forced out of work, the area became economically depressed, and alternative employment was unavailable. To alleviate the situation, a plan was set forth to have the fishermen become quahog farmers. The Florida Department of Labor funded Project OCEAN (the Oyster and Clam Educational Aquaculture Network), and $3 million was procured through the Job Training Partnership Act. The Harbor Branch Oceanographic Institution in Fort Pierce was contracted to train the fishermen. The county commissioners granted culture leases in their nearshore waters and they administrated the project, which was based in Cedar Key. About 138 people received the training, and each acquired a 4-acre lease to grow the quahogs. The leases are on sandy bottoms and most are 450–600 m offshore in 60 cm–2.4 m of water. The program was successful and a new industry on Florida's west coast was launched (Sturmer et al., 1997).

In 1994, the State Legislature dealt a severe blow to the Florida finfishing industry when it banned the use of gill and entanglement nets in coastal waters. The success of Project OCEAN led displaced net fishermen on the west coast to learn quahog culture through Project WAVE (Withlacoochee Aquaculture Vocational Education), which was also headquartered in Cedar Key. In 1996, 49 fishermen each received 2-acre leases and 76 fishermen were trained in land-based nursery techniques. An extension to Project WAVE ran through mid 1997 and retrained and placed 100 net fishermen in quahog culturing (Sturmer et al., 1997).

The Harbor Branch Oceanographic Institution provides about half of the quahog seed to the farmers, while several small private hatcheries operating throughout the state provide the remainder. Seed from the hatcheries is grown first in nurseries, which consist of 3-tiered raceways lined with plastic or epoxy and wellers which can be placed temporarily inside a raceway tray. The 60 nurseries in the state rear 1-mm seed to 5–6 mm, the minimum field-planting size, in 8–12 weeks. The seed is grown in polyester mesh bags, which serve as predator protection and when on the bottom accumulate sediments which serve as a substrate for the quahogs. About 1,000 quahogs are held in each bag. They grow to littleneck size (about 2 inches long) in 10–14 months. Farmers harvest the quahogs by lifting and emptying the bags (Sturmer et al., 1997).

Several factors converged to make quahog culture successful for displaced fishermen on Florida's west coast: 1) relatively low-level technology, 2) inexpensive start-up and operating costs, 3) no natural or wild fishery, and 4) ready markets. The quahog farming allowed fishermen to continue their independent way of life on the water (Sturmer et al., 1997).

The quahog farmers in the state increased in numbers from 41 in 1991 to 318 in 1997, while their seed plantings increased from 37 million to 306 million, their harvests of littlenecks from 8.8 million to 99 million, and dollar value of sales from 1.2 million to 10 million during the same period. The leaseholders occupy 950 acres of submerged bottoms (Colson and Sturmer, 2000). Production in 1998 fell, probably because poor environmental conditions caused by El Nino and La Nina led to low salinities and high water temperatures. The result was substantial losses of seed and marketable quahogs, but by the year 2000 production recovered.

Gulf States

Southern quahogs, *M. campechiensis*, have not been important commercially in the United States, except for several years in Florida in the early part of this century. They are relatively scarce, and a drawback to them as a product is their short shelf-life which lasts only a few days; they gape readily when out of water. Southern quahogs unfortunately grow relatively fast (up to 5 cm in their first year) and few high-value littlenecks and cherrystones are ever found (Dugas, 1980).

Southern quahogs grow in all U.S. Gulf states: Florida, Alabama, Mississippi, Louisiana, and Texas (Fig. 78). They occur in bays or sounds where salinities range from 15–40‰ but not in the Gulf of Mexico. In Alabama, they are rare throughout the southern half of Mobile Bay. In Mississippi, they are rare throughout St. Louis Bay and Mississippi Sound. In Louisiana, they are rare in Terrebonne, Timbalier, and Barataria Bays, and rare in most of Breton and Chandeleur Sounds, but common in eastern Chandeleur Sound. In Texas, they are common in Corpus Christi Bay, Aransas Bay, and in southwestern Matagorda Bay, but rare in San Antonio Bay, most of Matagorda Bay, and Galveston Bay (Anonymous, 1992).

Southern quahogs live in sand and silt-sand bottoms, and sometimes along the edges of seagrass meadows. Nearly all are large, mostly 75–100 mm long but range up to 150 mm long. According to Dugas (1980), the quahogs probably grow that much in 3–6 years, but most are probably much older and had attained their maximum sizes.

In 1904, some large beds of southern quahogs were discovered near the Chandeleur Islands, which form the eastern

border of Chandeleur Sound. Five beds, all having quahogs nearly uniform in size, were present over a distance of about 75 kilometers. On one bed, the quahogs were all about 15 cm long, while on others they were about half that size. No small quahogs and only a few small quahog shells were found (Spaulding, 1906).

Schroeder (1924) described another huge bed of southern quahogs in the Ten Thousand Islands area off the southwest coast of Florida. The bed was about 65 km long and 8 km wide. The quahogs averaged about 1 lb each (100 filled a bushel basket) and some weighed at least 2 lb Along this coast, the shore slopes gradually into the Gulf of Mexico. At 1.5 km offshore, the depth varies from 1.2–2 m at low tide, and from there to the 8 km line the slope is about 60 cm/1.5 kilometers. Seagrass thrived in nearly all the places where the quahogs were abundant. In most places where this grass was absent, few or no quahogs were present.

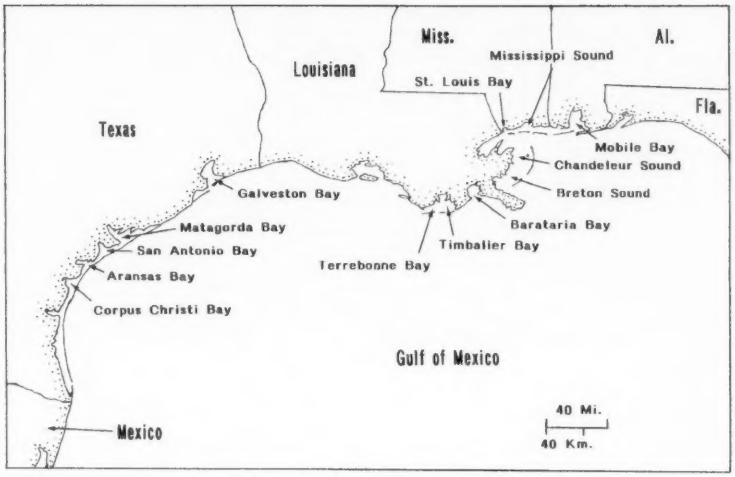

Figure 78. — Coastline of the U.S. Gulf of Mexico, Texas through Alabama, showing locations mentioned text.

Fishery

Schroeder (1924) said the quahogs off the southwest coast of Florida were being harvested by hand diggers and two dredging boats. Hand diggers located the quahogs with their feet and removed them from the mud with 2-tined forks (picks) having 15-cm handles. Each digger had a small flat-bottom boat to hold the quahogs as they were dug. From 1919 to 1922, 10–15 diggers were employed. Each dug 10–20 5-peck basketfuls/day and were paid $0.40/basketful. They worked close to shore during high tides and moved out as the tides fell. When a boat became loaded, the fishermen unloaded it in shallow water near shore. They made several daily trips to shore with their quahogs. A "run" boat took the quahogs to canneries.

One quahog dredging vessel was 27 m long, 6 m wide, and had 2 stories; it resembled a houseboat. Its digging apparatus was situated in its middle and was 1.8 m wide. The machinery and tool room was at one end, and storage space for the quahogs was at the other end. The second story was devoted to sleeping quarters and a mess room. The quahogs were conveyed to the surface where 1–4 men removed them and put them in baskets. The dredge boat moved slowly, i.e. about 30 m in 1.5 hr, harvesting 100–150 bu/run and 440–560 bu/day. During 1918, the vessel dug about 35,000 bushels. In 1919, it dug 43,000 bu and the hand diggers harvested 5,000 bu. In 1922, 2 dredging boats and the hand diggers combined to harvest a total of 206,000 bu of quahogs, nearly all of which were sold to 2 canneries. The larger cannery had an annual production of 100,000 cases of quahog meats and quahog juices (Fig. 79). The fishery, extant from 1905 to 1947, was extremely productive, with peak daily landings of 1,800 bu of mostly chowder-size southern quahogs (Schroeder, 1924; Godcharles and Jaap, 1973).

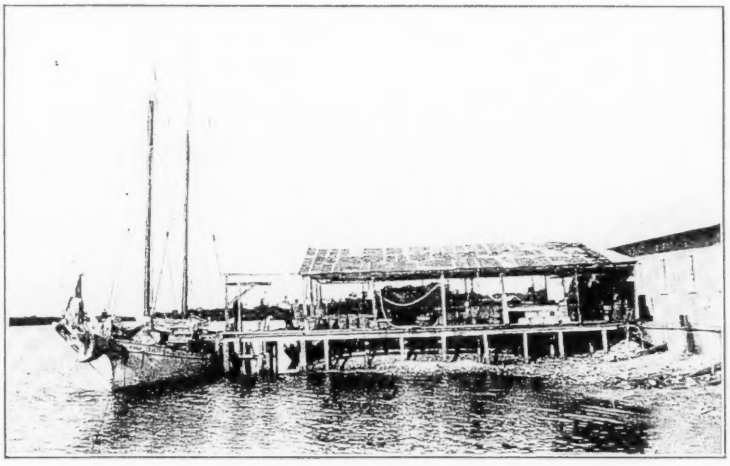

Figure 79. — The dock at Marco quahog cannery in Florida and freight boat ready to leave for Key West with cargo of canned quahog products. At Key West, the cases of quahogs were placed aboard a steamship for delivery to New York, N.Y., 1920's (from Schroeder, 1924).

In 1976, the State of Louisiana Department of Wildlife and Fisheries surveyed Breton Sound and found a sufficient quantity of southern quahogs to encourage a company to begin harvesting them in 1977. The company harvested 9,742 bu of chowder-size quahogs, but gave up late that year because the demand was small.

In recent years, nearly everywhere along the U.S. Gulf, southern quahogs have been too sparsely distributed to support a commercial fishery. There recently has been a small commercial fishery for them in Texas by people of southeast Asian descent, and, on a small scale, the quahogs are harvested by recreational fishermen who usually find them with their feet.

Mexico

Southern quahogs are present in high-salinity lagoons that are confluent with the Gulf of Mexico from the Mexican States of Tamaulipas in the north through Campeche in southeastern Mexico (Baqueiro, 1997) (Fig. 80). The specific name of southern quahogs, i.e. *campechiensis*, is derived from the name of the State of Campeche. The quahogs occur in Laguna Madre, Tamaulipas (Antoli and Garcia-Cubas, 1985); Laguna Tampamachoco in Veracruz (Garcia-Cubas and Reguero, 1990; Reguero and Garcia-Cubas, 1991; Reguero et al., 1991); Lagunas el Carmen (Antoli and Garcia-Cubas, 1985), Tupilco, and Mecoacan in Tabasco; and Laguna de Terminos and near Isla Arena in Campeche; and probably others. In Laguna de Terminos, their distribution is restricted and localized on the shoals of Punta Gorda (Garcia-Cubas, 1981). Quahogs are not found in Lagunas Pueblo Viejo, Camaronera, or de Alvarado (Reguero and Garcia-Cubas, 1989, 1991, 1993). The southeasternmost location in Mexico where southern quahogs have been harvested is by Isla Arena near the town of Celestun, Campeche, close to the Yucatan border. The harvesting there is sporadic; none occurred in 1999. Castillo et al. (1988) suggested the quahog could be a potential fishing resource in Campeche and Yucatan. They estimated that 7.3 t might be harvested annually and

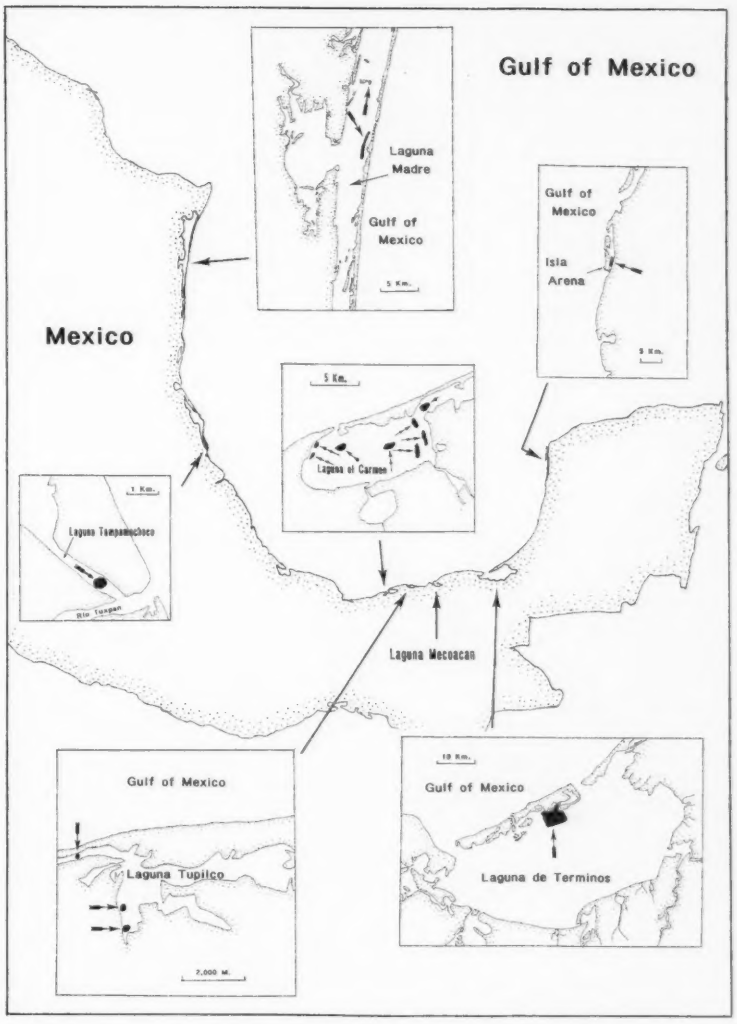

Figure 80. — Coastline of Mexico showing locations mentioned in text where southern quahogs are reported to occur. The arrows point to specific beds of southern quahogs; additional locations undoubtedly exist.

they recommended a minimum harvest length of 73 mm.

Southern quahogs are one of several clam species harvested in lagoons along Mexico's east coast. The Mexican Government has not established a harvest season or minimum size for quahogs. Together the clams contribute about 7% of the nation's total seafood production. Quahogs have been harvested for many years according to local residents, but the fishery is small because the stocks are small and market demand is low. No historical accounts exist of this fishery. Quahogs are harvested on a commercial scale mainly in Laguna del Carmen. In other lagoons, such as Laguna Madre, where quahogs are present in its lower portion, the harvesting is sporadic and is mostly for personal consumption. In the lagoons, the fishermen intersperse quahoging with catching shrimp, oysters,

and fish, with shrimping and oystering being the most important. The quahogs are sold whole and are shipped by truck on a small scale to various cities.

Clam Landing Statistics

Mexico's Federal Government official fishery statistics lump all clam species (Anonymous, 1997) and, therefore, landings of southern quahogs are not recorded. In 1997, clam landings (all species) in Mexico totaled 6,941 metric tons (t) (whole weight), of which the Pacific coast contributed 6,075 t, and the Gulf of Mexico coast contributed 866 t. In the Gulf of Mexico states, landings were: Veracruz, 834 t; Tamaulipas, 15 t; and Tabasco, 6 t (Anonymous, 1997). The Veracruz landings were mostly *Rangia* sp., but in Tabasco, they were mostly southern quahogs with annual landings ranging from 4.2 to 10.5 t (7.5 t, average).

Harvesting Methods

Quahogs can be harvested by anyone who has a fishing license issued by the Mexican Government. The quahog fishermen, all of whom are males with low incomes, live within walking distances of their boats. Harvesting in all lagoons is at wading depths. In Laguna del Carmen, which supports the largest fishery, about 20 fishermen harvest southern quahogs. They get to the beds in fiberglass boats that are about 7.6 m long and propelled by 15 hp outboard motors. Each boat carries as many as 9 fishermen who share boat expenses (Fig. 81). Fishermen leave the boats and wade in water, feeling for quahogs with their feet and collecting them by hand (Fig. 82). Fishermen tie pieces of cloth onto their feet to protect against cuts from oyster shells and some wear gloves, and, if in relatively deep water, a face mask. They place the quahogs in plastic boxes which have empty soda bottles or Styrofoam attached for flotation (Fig. 83). Oyster fishermen using tongs occasionally harvest small quantities of quahogs with the oysters.

Individual fishermen harvest quahogs in Laguna del Carmen no more than 4–5 days a week, the effort being governed by market demand and availability of shrimp and oysters in the lagoon. The fishermen often switch from one fishery to another, going to the one that brings them the most money. The harvesting days can be infrequent during the rainy season from October through December when rivers flood and water levels rise in the lagoon. Fishermen usually harvest quahogs for about 4 hr (10 a.m.–2 p.m.), and each gathers 200–250 quahogs/day (Fig. 84). Individual harvests can be lower during periods of low demand (Zapata[44]). In some other locations, such as in the Laguna de Terminos (harvests are near Isla La Arena), where the harvesting is sporadic, the fishermen bring the quahogs home to eat or to sell to their neighbors (Calderon[45]; Baqueiro[46]).

Markets and Marketing

Consumption of quahogs is limited due to the small supplies and Mexicans having little tradition of eating them. Most quahogs landed in Laguna del Carmen are not marketed in the State of Tabasco, but rather in the cities of Oaxaca (about 400 km away) and Mexico City (about 700 km away) (Vidal[47]). The remainder are sold mostly in the cities of Paraiso, Coatzacoalcos, and Villahermosa.

Quahogs are sold whole, some by weight, and some by the piece. In 1998, buyers paid fishermen 4.00 pesos (US$0.47)/kg. The price for individual quahogs varied according to their size. Buyers paid fishermen 0.40 pesos(US$0.047)/quahog 60 mm long (i.e. littleneck-topneck size for *M. mercenaria*), and 0.60 pesos(US$0.071)/quahog 80 mm long (i.e. cherrystone size for *M. mercenaria*) (Zapata[44]). The fishermen each earn 100 to 150 pesos (US$10.75 to $16)/day.

Quahogs are sold in a few fish markets and outdoor markets wherever fish are sold, but sales are small. A fish market in Coatzacoalcos sold them by the piece for prices between 1.00 and 2.00 pesos (US$0.12–$0.235) each (Perez[48]). A market in Villahermosa sold them for 2.00 pesos each.

A restaurant in El Bellote, Tabasco, serves about 3,000 quahogs a week, paying dealers 0.60 pesos (US$0.071) each for them, and charges 25 pesos (US$2.94) for a cocktail with 20 quahogs and 20 pesos (US$2.35) for a serving of 16 boiled or broiled quahog meats (Vasquez[49]). The meats are boiled with steam vapor, or broiled in fire using dried coconut branches as fuel. For broiling, the quahogs are placed on a grill and the smoke from the burning branches makes the shells black (Fig. 85); the local people call them "smoked quahogs" (Fig. 86).

Local Quahog Consumption

Fishermen take some quahogs home to their families, eating them about twice a week. The quahogs are usually prepared in three ways: 1) in cocktails, boiled quahog meats are combined in a glass with lemon juice, onion, chili, oil, salt, ketchup, hot pepper, and coriander; 2) cooked in soups with blue crabs, *Callinectes* sp.; shrimp; and oysters, or with rice (Fig. 87); and 3) served in their shells after being boiled; lemon juice, onion, chili, oil, salt, and ketchup are added to the meat (Torres[50]) (Fig. 88).

Aquaculture Prospects

Attempts to culture quahogs are being initiated in Campeche. Researchers are testing seed production methods to generate a reliable quahog supply for a local canning company which sells clam soup. The company now has to import quahog meats (Baqueiro[46]).

Government Regulations

In Canada, quahog harvests are regulated by various divisions in the Canadian Department of Fisheries and Oceans. In the United States, they are regulated by

[44]Zapata, R. Quahog fisherman, Sanchez Magallanes, Tabasco, Mexico. Personal commun., 1998.

[45]Calderon, A. Fisherman, Isla Aguada, Campeche, Mexico. Personal commun., 1998.

[46]Baqueiro, E. Researcher, Centro regional de Investigacion Pesquera, Campeche, Mexico. Personal commun., 1998.

[47]Vidal, R. Chief, SEMARNAP office, Sanchez Magallanez, Tabasco, Mexico. Personal commun., 1998.

[48]Perez, D. Saleswoman in fish market, Coatzacoalcos, Veracruz, Mexico. Personal commun., 1998.

[49]Vasquez, R. Restaurant owner, El Bellote, Tabasco, Mexico. Personal commun., 1998.

[50]Torres, M. Technician, SEMARNAP, Sanchez Magallanez, Tabasco, Mexico. Personal commun., 1998.

Figure 81. — Treading southern quahogs in Laguna el Carmen, Tabasco Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 82. — Treading southern quahogs in Laguna el Carmen, Tabasco, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 83. — Treading southern quahogs in Laguna el Carmen, Tabasco, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 84. — Southern quahog harvest from Laguna el Carmen, Tabasco, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 85. — Broiling quahogs with flames from dry coconut branches. The result is called "smoked quahogs." Ciudad del Carmen, Campeche, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 86. — Quahogs broiled with dry coconut branches (smoked quahogs). They are eaten after adding chili, onion, and lemon in Ciudad del Carmen, Campeche, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 87. — Soup with quahogs, shrimp, fish, and oysters in Ciudad del Carmen restaurant, Campeche, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

Figure 88. — Serving of boiled quahogs with condiments nearby in Ciudad del Carmen restaurant, Campeche, Mexico, 1998. Photograph by A. Wakida-Kusunoki.

individual states. In some locations, the first regulations were imposed in the late 1800's or early 1900's. In Mexico, where the fishery is largely unregulated, the Mexican Federal Government has jurisdiction over it.

No attempt will be made here to describe the histories of regulations in each country, province, and state. Instead, their early history in Massachusetts as described in Chapter 3 — Laws in Belding (1912) will serve as an example:

"Little direct quahog legislation has been passed as the quahog usually has been included in general laws with other commercial shellfish. Previous to 1904 the quahog, with the softshell clam, oyster and scallop, came in the general acts under the term shellfish. The general acts were of several kinds: (1) town regulation; 2) permits; 3) seizure in boats; and 4) protection of the shellfisheries by limiting the catch, place, and time of taking.

"In 1874 occurs the first mention of the word quahaug [sic] in a legislative act "to regulate the shellfisheries in the waters of Mount Hope Bay and its tributaries," whereby the selectmen of the towns bordering on Mount Hope Bay were permitted to grant licenses for the cultivation of clams, quahogs, scallops and other shellfish to any inhabitant.

It seems strange such an advanced and beneficial act should have been passed at that early period, since it was clearly before its time, as is shown by its repeal the following year.

"In 1880 the word quahog again appears in a general act whereby the Commonwealth gave to the towns and cities their present oversight and power 'to control and regulate the taking of eels, clams, quahogs, and scallops.' This act was later amended by the Acts of 1889, but the general terms were not changed, and the present law differs but slightly.

"In 1900 occurred the first special quahog legislation, in the form of an act forbidding in the towns of Swansea and Somerset the capture of quahogs less than 1.5 inches across the widest part (Fig. 89). Since that time several other laws, both general and special, relating to the quahog fishery have been enacted, especially in connection with the shellfisheries of Plymouth and Barnstable Counties. The following features are illustrated by these laws.

"The capture of quahogs under 1.5 inches across the widest part was forbidden by law in 1900 in the towns of Swansea and Somerset, in 1901 in Berkley, in 1903 in Edgartown, and in 1904 in Eastham, Orleans and Wellfleet. This law has also been adopted by other towns under the regulation of the selectmen, and is to be commended for the protection afforded to the local industries, as the gain for leaving the small quahogs for one year is approximately 5 bu for every bushel left.[51]

"*Permits*: In Eastham, Orleans, and Wellfleet the selectmen are empowered to issue permits for the capture of the quahog, while in other towns permits are issued for shellfish in general. Often the towns are slack about the enforcement of the law requiring permits, although Edgartown is to be commended for the excellent manner of regulating, by inspectors, her shellfish permits. These permits are given at the discretion of the selectmen, and usually require 6 months residence in the town. Different prices are charged for these permits: e.g. in Edgartown, $2, and in Wellfleet, $1. The provisions of the Edgartown permit limit the catch to 4 bu from sunrise to sunset, no more than 2 of which can be 'little necks.' The Wellfleet permits limit the daily catch to 4 barrels per man.

"*Bedding Quahogs*. In Eastham, Orleans, and Wellfleet the selectmen may give, for a period of not over 2 years, under such conditions as they may deem proper, to any inhabitant of the respective towns, license to bed quahogs in any waters, flats, or creeks where there is no natural quahog bed, not covering more than 75 ft square in area, and not impairing the private rights of any person or materially obstructing any navigable waters. The object of this law was to enable the quahog to take advantage of a favorable market. Undoubtedly the originators of this act did not foresee in this way they had taken the first step toward quahog farming, as the success of bedding quahogs has demonstrated the practical benefits which would be derived from quahaug culture.

"*Biological Investigation*: In 1905 the commissioners on Fisheries and Game were empowered to make a biological investigation and report as to the best methods, conditions, and localities for the propagation of quahogs. The results of that investigation are embodied in a report published in 1910.

"*Planting, Cultivation, and Bedding of Quahogs*: In 1909 the selectmen of towns or the mayor or aldermen of cities, provided the act was approved by the city council or by the voters of the town at an annual special town meeting, were empowered to issue written licenses for the purpose of planting and cultivating quahogs upon and in the flats and creeks below mean low-water mark, for a term of not more than 10 and not less than 5 years. The fact that up to the present time little advantage has been taken of that, which permits practical quahog culture being carried on, is another proof of the inability of the coast towns to properly adjust their point of view toward the practical means not only of preserving their natural supply from extinction but also of building up profitable business for the inhabitants.

Figure 89. — Measuring a northern quahog to determine whether it is of legal size, Prince Edward Island, Canada, 1998. Photograph by A. Morrison.

"*Contaminated Waters*: In 1901 it was enacted that the Commissioners on Inland Fisheries and Game (now the Division of Fisheries and Game), whenever so requested in writing by the Department of Public Health, should prohibit the taking of oysters, clams, scallops, and quahogs from the tidal waters or flats of any part of the Commonwealth for such period of time as the Department of Public Health might determine. Unfortunately the beneficial effect of this law, namely, the protection of public health by the closing of sewage-polluted areas, was rendered void by the passage of a bill of 1907 permitting the taking of shellfish from these areas for bait, upon securing permits from the local board of health. Effective enforcement was impossible on account of the ease with which proofs are destroyed by the violator and the difficulty of tracing any lot of polluted shellfish to their ultimate destination as human food. In the Acushnet River, where seed quahogs were abundant, a means was found to permit the sale of quahogs for planting purposes by the

[51]This statement suggests Massachusetts authorities ordered small quahogs be left in beds to grow so they would yield more. It was not that they wanted them to spawn at least once, or that the market wanted the larger quahogs.

passage of special regulations for the town of Fairhaven and the city of New Bedford. Transplanted to pure water, quahogs readily purify themselves from contamination."

Changes in Quahog Trade Sizes

In the 1970's, the quahog dealers in Long Island, N.Y., increased the prices of quahogs by first adding a new trade name, "topneck," for a new size category they created between littleneck and cherrystone, and they dropped the name "medium." They next adjusted the size categories used in the trade (Table 1). The topnecks are about the size of the original cherrystones, and the cherrystones are about the size of the original mediums. The trade then raised the prices of quahogs: The littlenecks were sold at a higher price, the topnecks were sold at the original littleneck prices and what used to be mediums at the original cherrystone prices. In the 1990's, as a consequence of a strong demand for quahogs, the sizes within each category have been increasing, and today some retail markets are selling "chowders" as "cherrystones" and selling them at cherrystone, and even littleneck, prices (Fig. 90).

In the 1980's and 1990's, cultured quahogs were often sold at smaller sizes than littlenecks to specialty markets because of different legal restrictions that apply to them, i.e. pasta necks, from 5/8 to 3/4 in (16–19 mm) wide; petite necks, 7/8 in (22 mm) wide; and littlenecks, 1 in (25.4 mm) wide (Batey[52]). But the size ranges vary considerably depending upon local tradition and conditions and on market demand.

The Quahog Fishermen

Many quahog fishermen are the sons of fishermen. If not quahogers, they would likely fish for other species or else be tradesman or laborers if they worked on land (Moonsammy et al., 1987; Gates, 1991). They are physically strong men who have to work hard to make a good day's pay. Ingersoll's (1887) description of coastal people who do not participate in harvesting quahogs remains apt today, "Women and children cannot do much at it because of lack of strength; lazy men will not attempt it because it involves too much exertion and steady diligence."

Most quahogers entered the fishery when they were in their teens and twenties during periods when quahogs were abundant, because the pay was relatively good, the training was minimal, and the initial investment in a small boat and rake was low. Some quahogers harvest between alternative seasonal jobs, and, in many localities, quahoging is a convenient summer job for high school and college boys. Because fishermen may have little training for other jobs, many remain in the fishery for many years even when quahog abundances are low and their income is minimal. Some leave the fishery by age 40 because work becomes too hard or if the quahog stocks become scarce.

Gatewood and McCay (1990) reported on job satisfaction among quahog fishermen. They said quahogers enjoy the healthfulness, peace of mind, opportunity to be one's own boss and to come and go as one pleases, doing something worthwhile, being on the water, and the challenge of pitting their skills against nature in their work. Quahogers have the same satisfactions that farmers have from producing a commodity, while they are least satisfied about the lack of predictability of their earnings.

Quahogers are relatively poor. Most rake quahogs just hard enough to support their families minimally, to avoid becoming overly tired and aging prematurely. They naturally oppose government regulations that would reduce their harvesting efforts and incomes. They have different priorities than do resource managers, asserting that the objective of management should be to ensure good harvests rather than the maintenance of the quahog resource. Nevertheless, many fishermen now appreciate the positive relationship between maintaining the resource and ensuring a good day's pay. For example, in Florida's Indian River Lagoon, quahogers realize their vocation can provide a steady income if the resource is conserved and maintained. In an attempt to achieve that goal, the quahogers requested and

Figure 90. — As the demand for quahogs has grown in the late 1990's, the sizes within established categories have become larger. In a Red Bank, N.J., supermarket, large chowder-sized quahogs are labeled as cherrystones and are priced the same as littlenecks, 1998. Photograph by C. L. MacKenzie, Jr.

Table 1. — Approximate size ranges (in inches) of various categories of quahogs used in the trade during the 1910's, mid 1990's, and late 1990's.

	1910's[1]	Mid 1990's[2]	Late 1990's[3]
Littleneck	1 1/2–2 1/4	1 7/8–2	1 7/8–2
Topneck		2–2 3/8	2–2 3/8
Cherrystone	2 1/4–3	2 1/2–3 1/8	2 3/8–3 3/4
Medium	3–3 3/4		
Chowder	>3 3/4	>3 1/8	>3 3/4

[1] Data from Belding, 1912.
[2] Data from Hadley et al., 1997.
[3] Data from New Jersey dealers.

[52]Batey, C. Husbandry Supervisor. Sea Perfect. 2107 Folly Road, Charleston, SC 29412. Personal commun., 1998.

were granted a license that limits entry into the fishery and provides funds for government and private industry research relating to quahog conservation and enhancement.

Quahogers have been active in management in other locations as well. Those who harvested in Great South Bay, N.Y., during the 1960's and 1970's were perceived as an important political force and were extremely vocal in their opinions regarding management of the quahog resource. Local governments in that area saw them as a major constituency and many politicians felt the fishermen knew what was best for the bay and resource (Anonymous, 1985). Elected officials rarely implemented any proposals by shellfish managers and researchers that lacked the popular support of the quahog rakers and dealers (Kassner, 1988).

Fishermen remain critical of government agencies if they fail to enhance depleted quahog resources. An action they have supported is transplanting quahogs from uncertified beds to certified beds. When proposals are made that further their interests, quahogers want immediate action. They commonly are skeptical of the need for additional scientific research, because they have seen too few practical results from it. They are suspicious or hostile to any action that would place research before practical action (McCay, 1988).

A reason fishermen often challenge management decisions is they believe they understand the causes for declines in quahog abundances and other features on the beds that affect their livelihood and believe management authorities are ignorant of bed conditions when they make decisions. Sometimes the fishermens' assessments of conditions are correct, and sometimes they are incorrect.

Poaching of quahogs by fishermen in uncertified or closed beds where quahogs may be more abundant than in certified beds has been a problem in the quahog fishery. The fishermen, who knowingly violate laws designed to protect public health and the long-term health of the fishery, do so because the income potential is high. Those fishermen threaten the continued existence of the entire shellfishing industry.

Figure 91. — Local governments try to support their fisheries, such as the blue crab and clam (quahog) fisheries, in Ocean County, N.J.

Community Views of Industry

Coastal communities are aware quahoging involves more heavy labor and can be a less reliable money-earner than most jobs. Nonetheless, in localities where quahog fishing supports a large number of fishermen, citizens view the fishery as a major supplier of jobs and income both directly to the fishermen and indirectly to those who supply the support structure for those fishermen. Some are also aware it is a continuation of one of America's first industries and thus view it warmly. The communities obviously want the fishery to support as many people as possible in a stable, prosperous condition (Fig. 91).

As in any fishery, the "multiplier effect" is an important consideration in this fishery. For example, in Rhode Island, the economic multiplier for the shellfishing industry is 4.5, the highest of any state industry (Kadri, 1991). When a quahoger earns money, he spends most of it in the local economy on fishing equipment, food, and real estate. The quahogs are purchased by dealers who sell to local restaurants where many tourists eat, and the profits of shellfish dealers and restaurant owners pump more money into the regional economy.

Quahog harvesting effort tends to respond inversely to changes in community unemployment rates. For example, in Rhode Island, from 1945 to 1970, the correlation between the number of quahog licenses issued and the unemployment rate was about 0.8 (Gates, 1991). The fishery acted as a "sponge" to soak up unemployed workers and provide them with employment. Of course, this effect is ultimately limited by the availability of quahogs and markets.

Relation of Quahoging to Other Fisheries

Seasonal Employment

As mentioned, in only a few areas have fishermen earned their entire livelihoods from harvesting quahogs. Examples of work in mixed fisheries are numerous. In the Maritime Provinces of Canada, many fishermen harvest quahogs during the spring and summer and harvest oysters from September through December. Although some are unemployed during winter, many trap rainbow smelts, *Osmerus mordax*, to generate income.

In southern Massachusetts and Rhode Island, fishermen once dug quahogs in the spring and summer and then shifted to harvesting bay scallops in the fall and winter (Fig. 92). But in recent years, with the demise of bay scallop populations in many bays, fishermen have ceased fishing entirely during the fall and winter months.

In New York and New Jersey, many fishermen once harvested quahogs part-time. But in recent years, most of the Great South Bay fishermen, now numbering only 100–150, harvest quahogs throughout the year although a few harvest the channeled whelk in the spring. From about 1825 to 1925, many Raritan Bay fishermen dredged seasonally for quahogs, oysters, and blue crabs. During the spring and summer, they harvested quahogs, then from September into January they dredged for oysters, and during the late winter they dredged for blue crabs. From 1946 through 1961, the Raritan Bay fishermen who harvested quahogs with rocking-chair dredges during the cold months shifted to scup, *Stenotomus chrysops*, fishing with otter trawls in the summer, while fishermen who operated pound nets in the spring and early summer shifted to sail dredging for quahogs during late summer and then dredged for blue crabs in the winter (MacKenzie, 1992a). McCay (1984) noted the relatively predictable abundance of quahogs in Raritan Bay, coupled with the minimal capital and technology required to harvest that resource, provided an effective buffer against downturns in other fisheries and the general economy. Quahoging, like crabbing and at one time oystering, provided a good fishing opportunity for part of the year. She also said the ability to turn to quahoging and other low investment activities also meant fishermen who worked for owners of pound nets and Atlantic menhaden, *Brevoortia tyrannus*, seiners had some control over the conditions of their labor, because they had alternative fisheries to which they could turn if necessary. Many New York and New Jersey fishermen now harvest quahogs nearly full-time.

In the coastal areas from Delaware Bay to North Carolina, fishermen harvest quahogs primarily during the summer and fall. During the winter and spring, many fishermen once shifted to oystering, while others fish for blue crabs or beach seine for striped mullet, *Mugil cephalis*, and white mullet, *M. curema*. In North Carolina, quahog "kicking" (washing quahogs from the sediments with propellers) is a wintertime occupation.

Figure 92. — Fishermen harvesting bay scallops, *Argopecten irradians*, Katama Bay, Mass., in December, 1950's. They used the boats when harvesting quahogs with short rakes, basket rakes, and bull rakes on the same grounds during the summer months.

In South Carolina, the harvesting of wild quahogs is restricted to a season open from 15 September until 15 May or 1 June. In the off-season, many quahogers work on shrimp boats so they often do not begin harvesting quahogs until around the first of the year when shrimping ends. In some areas around Awendaw, S.C., women and children harvest quahogs in the fall. The escalator dredges that harvest from restricted areas must wait until the water warms where the quahogs are to be relayed. This confines the harvest time to spring as most of those involved in this fishery are shrimping in the fall when temperatures are also suitable for depuration (Leland[42]).

In Florida, especially in the Indian River Lagoon, quahog fishing proceeds year-round. Because quahog production in northern states is often down in the winter, the demand for and value of Florida quahogs peaks then. The Florida quahogers then must share the resource with seasonal participants migrating into the fishery from Florida and coastal states to the north, though, in recent years, seasonal participation in the Indian River Lagoon quahog fishery has been restricted because licensing requirements mitigate against the large influx of out-of-state quahogers previously experienced (Chapters 94-419 and amendments, Laws of Florida). But during hard times (e.g. low quahog abundance or low price), even the most dedicated quahogers must find alternative work. Before 1995, net fishing for striped and white mullet and spotted trout, *Cynosion nebulosus*, was a common alternative, but the constitutional net ban in Florida (Chapter 370, Florida Statutes) has severely restricted that activity. Many quahogers now shift to blue crabbing or land-based work, while others try to develop successful quahog aquaculture ventures as a supplement to or as a substitute for the wild quahog fishery.

Effect of Surfclam Fishery

Large quantities of surfclams, *S. solidissima*, began to be landed in the eastern United States after the mid 1940's, when beds were discovered on the inner Continental Shelf off New Jersey and the Delmarva Peninsula. Soup companies soon replaced chowder quahog meats with surfclam meats in canned New England and Manhattan style chowders, bringing a loss of much of the market for chowder quahogs. The fishermen afterward did not retain as many chowder quahogs when they were harvested with littlenecks and cherrystones, because the market demand became minimal and their price low. But in recent years, more chowder-sized quahogs have been landed. Retailers dice them and make them into stuffed quahogs or quahog chowders, and sell some as cherrystones.

Effect of Aquaculture Development

In the 1970's, limited wild stocks of quahogs in bays along the eastern seaboard of the United States, coupled with a sharply increased demand and prices for littlenecks and the development of methods for culturing quahogs, stimulated the development of a quahog culture industry. Several states from Massachusetts to Florida now are producing large quantities of littlenecks, by growing hatchery-reared seed on their grounds.

Public-ground quahogers have been uneasy about the development of the hatchery-growout quahog culture, because private leasing of grounds removes some of their harvesting areas and cultured quahogs compete with their quahogs in markets. For example, in the early 1990's the price of littleneck quahogs fell by a few cents apiece and open-water quahogers blamed the influx of cultured quahogs for that price depression. But Hsiao et al. (1986) found the disposable income of consumers was the most important factor in determining the dockside value of quahogs and not quahog availability. In the late 1990's, demand usually exceeded quahog supply, at least during the summer months, and landed prices were high due to a strong U.S. economy. The allocation of quahog grounds may be a more substantial long-term source of conflict between open-access diggers and aquaculturists. In Florida, careful allocation of bottoms to aquaculture based upon past patterns of quahog production may alleviate this problem to some extent.

Quahog Management Programs

State agencies and local town governments have tried to manage quahog fisheries to protect the resource from depletion while providing optimum economic benefit to the fishery. These goals require wise planning if they are to be met. Management generally falls in five categories: gear restrictions, size limits, daily limits, closed seasons, and transplanting. Other programs have been environmental enhancement and hatchery-growout production.

A universal rule in every state and province mandates seed quahogs be left in the public beds. Quahogs once had to be at least 2 inches in greatest length to be taken. The rule satisfied the market's needs for littlenecks to be about 2–2 1/3 inches long and, besides, the male and female quahogs could spawn at least one summer before being harvested, and a larger volume of quahogs would be harvested. In recent years, the universal minimum size has been lowered to a 1-in width (1.5-in length). Both sexes can still spawn during at least one summer.

In addition, some states have imposed daily limits on each fisherman's harvest. For instance, during the 1950's at least, the fisherman's daily limit was a total of 4 bu of quahogs with no more than 2 bu of littlenecks taken in the town of Edgartown, Mass.; similar restrictions continue.

North Carolina's primary management goals are to provide appropriate access to all user groups, protect critical habitats from destructive harvesting practices, and still maintain a viable fishery. Management regulations include a daily bag limit per person or boat, and potentially a limited entry system.

In Florida, a limited entry system has been established for the Indian River Lagoon fishery. New quahog licenses are not granted until the number of licensed quahogers falls below 500, after which no more than 500 licenses will be assigned at any time. Quahogers currently holding licenses may keep them, but they must be renewed every three years, and renewal requires a certificate of completion of a quahog education course. The requirement severely restricts the license availability for itinerant quahogers. Such a program will mean more stable supplies available in the beds for the fishermen and more stable production for markets.

Through the years, quahog stocks on beds sometimes have become scarce forcing the fishermen to seek different employment. The means to maintain adequate stocks on the beds was unavailable to communities in the 1800's and early 1900's. Two researchers, David Belding (1912) and William Kellogg (1917) suggested planting quahog seed in beds. The seed would be raked from shallow public beds and planted on shallow plots. But when tried, this was rarely successful because the abundance of wild quahog seed usually is too sparse to collect in quantity. The following parts of this section describe the steps that have since been taken to enhance quahog abundances.

Transplanting Quahogs

The transplanting of seed and market-sized quahogs on a large scale has taken place for many years. In the 1930's, leaseholders in Barnegat and Chincoteague Bays purchased seed from harvesters in Raritan Bay and perhaps other locations to plant on their leases for subsequent growth and harvest (MacKenzie, 1992a). The practice of planting seed on leases in intertidal or shallow areas in Chincoteague Bay continued into the 1950's (but the seed did not come from Raritan Bay after the mid 1930's). Another practice which Chincoteague Bay quahog shippers used was to purchase market-sized quahogs from local harvesters during the warm months, plant them on intertidal flats or in floats, and reharvest them during the winter when the market demand and prices were highest (Boynton, 1970; Castagna, 1985).

In several states, seed and adult quahogs have been harvested from polluted areas and planted in clean waters for depuration, growth, spawning, and subsequent harvesting. Transplants in Rhode

Island, which involved moving quahogs from polluted grounds to state public grounds in certified waters, totalled an average of 25,825 bu/yr from the Providence River to Greenwich Bay and coves in Narragansett Bay between 1954 and 1968. The transplants ended after 1968 due to a lack of funding. In 1978 the program was revived and has continued ever since, but the quantities are smaller: About 2,500 bu were transplanted from coves off Greenwich Bay each year. The fishermen who carried out the transplanting were paid $0.10/lb for the work (Pratt, 1988). The program expanded after 1995, and increased to 8,000 bu in 1998 and to 15,000 bu in 1999 (Ganz et al., 1999). This Rhode Island program was initially conceived as a "put and take" operation in which quahogs were planted in the late summer or fall, to be cleansed and harvested during the winter fishing season. In 1981 the program was restructured so the bulk of the transplanting was carried out in the spring so the quahogs could spawn before being harvested (Pratt et al., 1992).

In other states, the primary purpose of transplanting was depuration. Quahog transplanting in Connecticut usually has been done by companies which move quahogs from polluted grounds to certified grounds for cleansing. In the past, the Tallmadge Company of Norwalk has transplanted quahogs using hydraulic dredges from upper Norwalk Harbor and New Haven Harbor to certified grounds for depuration. And in Oyster Bay, N.Y., the F. M. Flower Co. has transplanted quahogs, using hydraulic dredges, from polluted grounds also for depuration.

Management practices in North Carolina include relaying quahogs from closed waters to public bottoms by State-owned boats and private fishermen. In the future, the use of locked steel cages and the necessity of constant enforcement surveillance may be incorporated to reduce the risk of theft. The cages are superior to direct on-bottom relaying in terms of ease of recovery, reduced mortality, and reduction of grit in the meats (Taylor, 1995).

In Indian River Lagoon, Fla., fishermen harvest quahogs from restricted shellfishing waters for planting on private leases. After a minimum of 2 weeks, the quahogs can be reharvested for sale. Fishermen also bring quahogs to depuration facilities for a minimum 72-hr stay. When doing so, they receive less money per quahog than the leaseholders receive, but obtain it immediately and do not need a lease. In 1999, most depuration plants in the Indian River Lagoon were closed due to a lack of demand. The relay activities led to the discovery of new quahog beds throughout the Indian River Lagoon and to increased efforts by the state to reclassify the areas for quahog harvesting.

Spreading Shell and Oysters

South Carolina shellfishermen have found a combination of oyster shells and seed oysters spread over bottoms enhances quahog abundances. The method consists of covering an area having a history of good quahog sets with a layer of seed oysters and shell to about 5 cm thickness. It appears the combination of the two yields far more quahogs than just bare shell (Ashley[34]). Mine tailings with high lime content are added in some areas, and this seems to enhance recruitment. The market-sized oysters and quahogs in the beds are taken up by escalator harvesters 2 years after the oyster seed and shell are spread. The seed oysters and shell are returned to the bottom, and the beds continue to produce quahogs in subsequent years (Ashley[34]; Baldwin[39]).

No one has ever tried to enhance quahog seed abundance by planting clean sand, a good substrate for larvae setting. This is analogous to the oyster industry planting clean shell as cultch for oyster larvae.

Hatchery Production

Some of the most substantial advancements in quahog propagation consist of rearing quahog larvae in hatcheries and then growing the seed in nurseries and finally in growout beds to market size. The germination of the idea for quahog hatcheries could be said to have begun in the 1870's, when Brooks (1879) developed the method of artificial fertilization of American oyster eggs, and later in 1894, when an act of the Rhode Island legislature permitted the planting of shellfish in Narragansett Bay. At the time, land farming comprised a major part of the U.S. economy and fish hatcheries had been constructed to stock ponds and streams. Nothing materialized in Rhode Island because the law was repealed the following year, but, in 1904, a special law permitted the bedding of quahogs in three towns on Cape Cod, Mass.

In 1906, Julius Nelson in New Jersey described his experiments designed to propagate oysters in hatcheries. He stated, "The ultimate aim of our experiments is to make it possible to raise oysters by artificial fertilization in hatcheries, just as is now done with fish" (Stafford, 1912). In 1909, a Massachusetts law was passed which gave towns the option of giving grants to citizens. This "bedding" act was given for the purpose of holding quahogs for market and for growing purposes (Belding, 1912). Belding (1912) in Massachusetts said people such as William Kellogg (1901, 1910) were discussing the farming of softshell clams (*M. arenaria*), and he suggested they consider farming of quahogs also, because quahogs were far more hardy than softshells and the beds were carrying far below their capacity of this species. Belding (1912) was able to spawn quahogs, rear their larvae to setting size and beyond, and describe the anatomy of the developing stages. But methods for obtaining quahog seed by spawning and rearing the larvae to settlement sizes for planting were not yet developed for commercial-scale operations. William Wells (1927) and Herbert Prytherch (1924) on Long Island, N.Y., did rear some oyster and quahog larvae to setting size, but their equipment was primitive and foods for the larvae were not consistently good.

In the 1940's and 1950's, a goal of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) Biological Laboratory at Milford, Conn., was to develop reliable methods for spawning quahogs and growing their larvae to setting size consistently so commercial hatcheries and farms could be established. An important observation was oysters (and later quahogs) held in winter at summer temperatures would develop their gonads and spawn (Loosanoff,

1945). During those years, the laboratory improved and aggressively publicized the methods of rearing quahogs and oysters (Loosanoff and Davis, 1963). One such publicity paper (Loosanoff, 1959) in The Progressive Fish-Culturist was titled, "You, too, can now hatch clams." The Milford Laboratory also founded a program termed "Operation Baby Clam," that consisted of the laboratory producing thousands of seed quahogs to a size of 10–15 mm and then shipping batches of 3,000–4,000 seed to United States and European researchers to grow. Its purpose was to encourage those researchers to construct pilot hatcheries to produce quahog seed; the pilot hatcheries would be prototypes which local companies could use to construct commercial-scale hatcheries to produce quahog seed for their beds (Davis, 1969).

Various researchers and commercial hatcheries have since refined the Milford Laboratory larval-rearing techniques, mainly by improving equipment and foods. But predation, mainly by crabs, throttled efforts to make commercial operations feasible. Few seed planted in any unprotected beds survived the predators. In 1977, Castagna and Kraeuter showed when gravel and crushed stone was spread over quahog seed in beds its survival to market size was sufficiently high to permit commercial-scale farming. A huge improvement over stone was the use of monofilament mesh screens spread over the quahog seed plantings to protect them from predators; the idea for substituting screens for gravel and stones came from a commercial grower, named Richard Crema, in New Jersey (Kraeuter and Castagna, 1998). The screens are available in ample quantities, they are easy to use in contrast to gravel and stones, and now are used by almost all quahog farmers from Cape Cod to South Carolina.

Castagna and Kraeuter (1981), Manzi and Castagna (1989), and Hadley et al. (1997) have since published rearing manuals to be used by commercial quahog farms. They describe methods for spawning, rearing, and growing quahogs on beds. In recent years, quahog farms using hatchery-reared seed have been expanding in number and size in several states from Massachusetts to Florida as the market demand for quahogs, especially littlenecks, has grown (MacKenzie and Burrell, 1997).

South Carolina has a "state-of-the-art" quahog mariculture facility in operation (Fig. 93, 94). Its culture regime is as follows:

Quahogs to be spawned are conditioned for 6–8 weeks at 18°C. They then are temperature shocked at 25°–28°C, and if ripe they spawn. As they spawn the females are isolated, and after 2 hr eggs are collected in a bucket and sperm are added. About 150,000,000 fertilized eggs are placed in a 3,000 L tank; the density of eggs is about 50/ml. After 24 hours, the tanks are drained and veligers are restocked at 6/ml. They remain in the larval culture system for 7 days. Each day the cultures are drained down on increasingly larger mesh screens. On day seven, all larvae retained on a 125μ sieve are transferred to the post-set system. Larvae smaller than 125μ are discarded.

The post-set system is a downweller which is drained down every day and replaced with fresh seawater (Fig. 95, 96). The larvae are sieved once a week. They remain in the post-set system 30–45 days until they are retained on a 790μ screen (1-mm quahog). The 1-mm quahogs are moved to an upweller system and are fed ambient food (Fig. 97). Heretofore, the larvae had been fed cultured algae (Fig. 98–100). The quahogs in the upwellers are cleaned about 3 times a week. When they reach 2.4 mm they are moved to outside upwellers (Fig. 101). They remain in this system until they reach 4–8 mm (about 8–12 weeks old, depending on season) and then are put in a field nursery system.

The field nursery system in warm months is made up of either one or two systems. One consists of 1 × 3-foot plastic mesh bags, stocked 5,000 seed per bag. The bags are placed in the intertidal zone in 150-bag strings. The other field nursery system consists of 8-foot circular trays constructed of PVC pipe draped with vinyl mesh to form sides and bottom and covered with monofilament mesh (Fig. 102, 103). Quahogs remain in the systems until they reach 12–15 mm. This takes 2–6 months according to the time of year.

The 12–15 mm seed then are placed on the bottom and covered with 6-mm monofilament mesh in 3 × 15-m units. They are stocked at about 700/m^2 and then left for 20–24 months until they reach harvest size and can be harvested with hand rakes. Before shipping, the quahogs are run through a filter system of ultraviolet-treated water for at least 24 hours to ensure the meats are certified. Most are sold to wholesale distributors, but some go to retail outlets (Batey[52]).

The quahogs are graded (Fig. 104) and sold in 3 sizes: pasta neck, 5/8–3/4 in thick; petite neck, 7/8 in thick; and littleneck, 1 in thick. Package sizes run from 12 to 250 count, and most are trucked or air freighted out of the area (Batey[52]; Grant[53]). Aquaculture production estimates are confidential (Moran[54]), but a newspaper quoting authorities at the major aquaculture facility said about 10 million market sized quahogs and over 200 million 1-mm seed are produced annually (Langley, 1998).

One entrepreneur is using a tidal-powered upwelling apparatus to raise seed quahogs from 1 to 6 mm size. The seed are purchased from a hatchery in Maine and raised in this system and then sold to quahog farmers for growout. The apparatus consists of a raft that has a scoop to bring in water and pass it through caged seed similarly to a shore-based upweller (Fig. 105). The raft is moored so that the scoop end always faces the current. Location is the prime requisite for a successful operation, i.e. sufficient depth, current, available food, and enough area to allow 360° swings in the tide are required (Baldwin et al., 1995; Baldwin[39]).

Recommendations for the Quahog Industry

Our broad historical overview of the quahog industry in Canada, the United States, and Mexico has made it possible for us to suggest ways to enhance it. We have examined environmental features

[53]Grant, K. General Manager, Sea Perfect, 2107 Folly Road, Charleston, South Carolina. Personal commun., 1998.

[54]Moran, J. 1998. Head, Fisheries Statistics Section, South Carolina Marine Resources Department, P. O. Box 12559, Charleston. Personal commun., 1998.

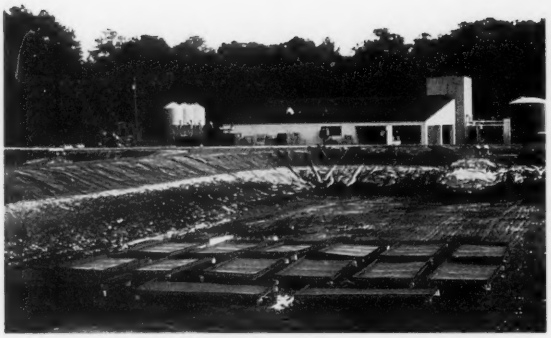

Figure 93. — Experimental tray studies of quahog growth and survival in ponds at the Waddell Mariculture Center, Bluffton, S.C., 1998. Photograph by V. G. Burrell, Jr.

Figure 94. — Preset larval culture tanks. Quahogs are grown until they are retained on a 125μ screen, Sea Perfect hatchery, Folly Beach, S.C., 1998. Photograph by V. G. Burrell, Jr.

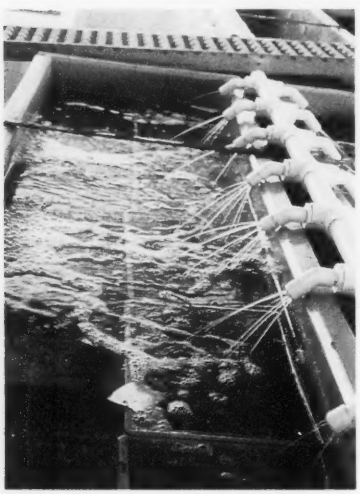

Figure 95. — Downwellers carry postset quahogs to 1 millimeters. Sea Perfect hatchery, Folly Beach, S.C., 1998. Photograph by V. G. Burrell, Jr.

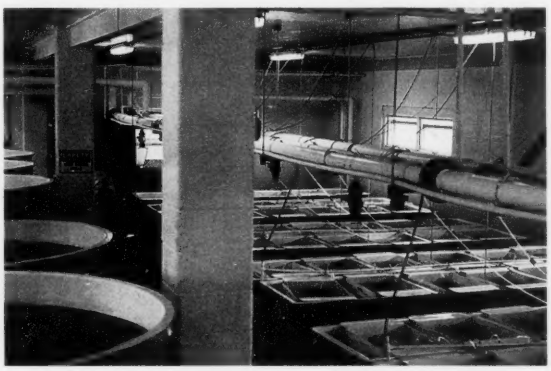

Figure 96. — An array of downwellers. Sea Perfect hatchery, Folly Beach, S.C., 1998. Photograph by V. G. Burrell, Jr.

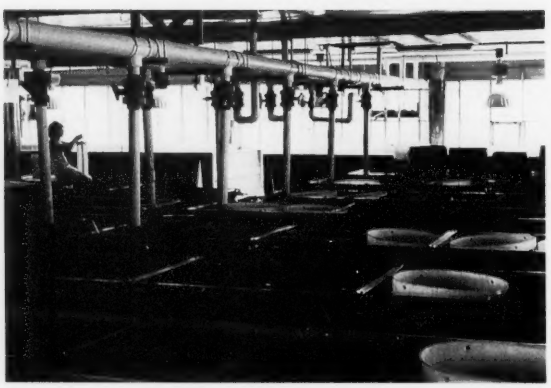

Figure 97. — Upweller tanks used to grow qua-hogs from 1-2.4 millimeters. Sea Perfect hatchery, Folly Beach, S.C. Photograph by V. G. Burrell, Jr.

Figure 98. — Algae culture system. Carboys are inoculated with selected species of algae. Sea Perfect hatchery, Folly Beach, S.C. Photograph by V. G. Burrell, Jr.

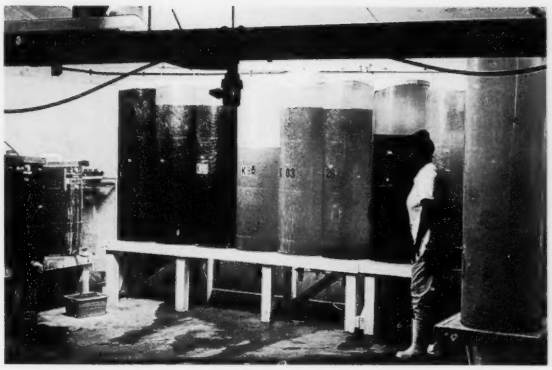

Figure 99. — Algae culture system. Calwell tanks are seeded from carboys. Sea Perfect hatchery, Folly Beach, S.C. Photograph by V. G. Burrell, Jr.

Figure 100. — Algae culture system. Final batches are produced in 3,000 l tanks which are then fed to quahogs. Sea Perfect hatchery, Folly Beach, S.C. Photograph by V. G. Burrell, Jr.

Figure 101. — Upwellers used to grow quahogs from 2.5-5 or 6 millimeters. Sea Perfect hatchery, Folly Beach, S.C. Photograph by V. G. Burrell, Jr.

Figure 102. — Quahog growout pens at ebb tide, Folly Beach, S.C. Photograph by Loren Coen.

Figure 103. — Quahog pens deployed on intertidal flats, Folly Beach, S.C. Photograph by Loren Coen.

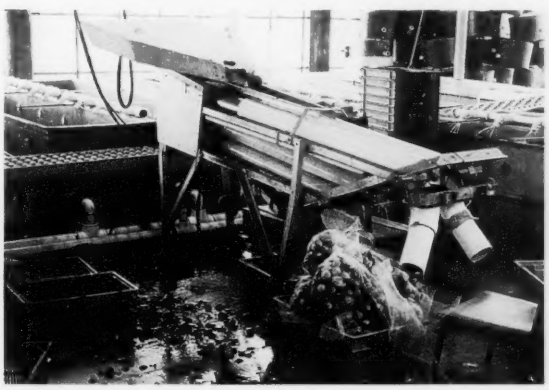

Figure 104. — Quahog grader where quahogs are sorted for packing and shipping Sea Perfect hatchery. Photograph by V. G. Burrell, Jr.

of the bays where quahogs have been abundant and scarce. In addition, we have studied various management and culture operations, as well as the species' biology and ecology. Aside from modest shell and oyster plantings for enhancement in South Carolina, little has been done to modify the habitats of natural beds to enhance quahog abundances such as spreading shells to collect spat and controlling predacious starfish and oyster drills, practices that have been successful with oysters. About the only feature common to oyster and quahog management has been transplanting stocks among beds, the oysters being cheaper to transplant because they dwell on rather than under the bed surface. To enhance the quahog industry, we recommend two new actions: 1) certain inlets should be enlarged and 2) starfish should be controlled.

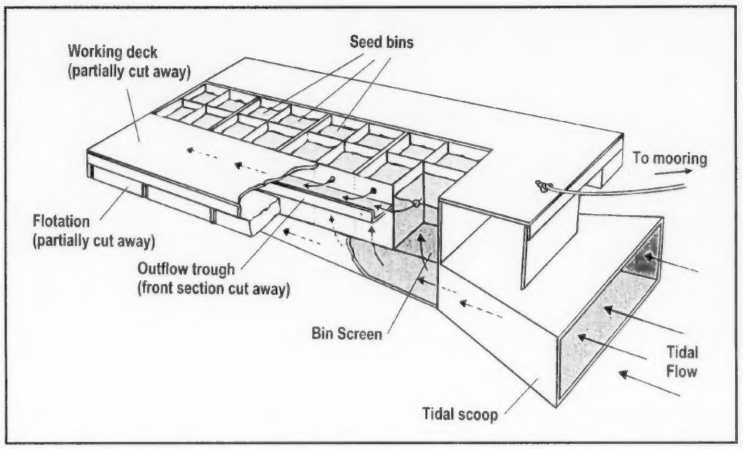

Figure 105. — A floating nursery upweller system that is tidally operated (S.C. Sea Grant illustration).

Enlarge Inlets

To our knowledge, no one has ever created inlets or enlarged the sizes of existing inlets between bays and the ocean for the purpose of enhancing abundances of quahogs or any other shellfish. But during the 1980's, authorities in Prince Edward Island widened the inlet across the West (Eliot) River to relieve a eutrophic condition that had developed in it every summer. The eutrophic condition afterward did not occur and oysters became much more abundant. Most other enlargements or maintenance dredging have been done to provide passageways for boats. Nevertheless, we suggest enlarging inlets, or at least digging large channels through the deltas inside inlets, such as Great South Bay and the coastal bays of New Jersey to allow a greater exchange of bay and ocean waters. This should enhance quahog abundance and the quahog fisheries in those bays. The purpose would be to relieve the eutrophic conditions in the bays and return the natural algae to their waters. If done, the quahogs would likely become much more abundant and match their earlier high densities and their meats would not become "black." The general "health" of the bays would improve, the invertebrates associated with quahogs would increase in abundance, and sportfish would likely become more abundant.

A restoration of quahog production in Great South Bay to a level of about 350,000 bu/yr, or half its peak production in 1976 would have a current landed value of about $20 million/yr (using a conservative value of $60/bu). This amount would seem to justify the costs involved in enlarging the bay inlets, which would range between $2 million and $4 million. Unfortunately for the quahoging industry, the shorefront residential property along the mainland shores of Great South Bay and Barnegat Bay is highly valuable and larger inlets might make it more vulnerable to storm damage. Perhaps the designs of larger inlets could be made in such a way that the potential for storm damage would be minimized. For instance, a stone wall, perhaps 1.0 km long, could be installed in the bays opposite the widened inlet to protect the mainland property from storm damage yet allow currents and vessels to pass freely by it. Construction of a stone wall would add to the cost of such a restoration project.

Control Starfish

MacKenzie and Pikanowski (2000) observed a negative correlation between starfish and quahog abundances in Raritan Bay and Long Island Sound (Connecticut). During the 1990's, the starfish became scarce and the quahogs became abundant in both locations. Starfish are a quahog predator and it seems likely the absence of starfish led to the increases in quahog abundances. Starfish could be removed from beds with mops if they were to increase in abundance and were reducing quahog abundances. The use of mops to remove starfish from oyster beds by oyster growers in Long Island Sound was first recorded by Ingersoll (1881), and they have been used for this purpose ever since.

Other actions

Other types of management actions being used such as transplants and hatchery seed planting for enhancement of stocks are highly recommended. Control of harvesting effort has helped to stabilize the earnings and employment for local fishermen in some areas.

Deliberate actions to protect spawning stocks appear to be unnecessary because fishermen always leave adequate quantities of spawners in beds when the harvesting becomes unprofitable to continue. The number of quahogs that set is likely independent of the sizes of spawning stocks. A relatively small number of spawners can provide large sets to beds when environmental conditions are good for spawning, larval development

and setting, and seed survival. Another unnecessary action may be stock assessments, except to determine the quantities available in polluted beds for planning transplanting operations. A rough measure of stock distribution and size in certified beds can be assessed by interviewing fishermen. The information determined by any earlier assessments has not had any practical value, except in the case of South Carolina to determine the opening of beds for harvest in the Santee River estuary (Rhodes et al., 1977).

Acknowledgments

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Literature Cited

Adams, C. 1988. No title. *In* D. Busby (Editor), An overview of the Indian River clamming industry and the Indian River Lagoon, p. 7–8 . Fla. Sea Grant Extension Program Tech. Pap. 44.

Anderson, W. D., and W. J. Keith. Undated. Management of a hard clam escalator harvester fishery. Unpub. Draft. S.C. Wildl. Mar. Resour. Dep., 20 p.

_____ , W. J. Keith, F. H. Mills, M. E. Bailey, and J. L. Steinmeyer. 1978. A survey of South Carolina's hard clam resource. S.C. Wildl. Mar. Resour. Dep. Tech. Rep. 32: 17 p. + app.

Anonymous. 1985. Suffolk County's hard quahog industry: an overview and an analysis of management objectives. Mar. Sci. Res. Cent., SUNY. Stony Brook. Spec. Rep. 63, 374 p.

_____ . 1987. L. I. Green Seal Inc. Final report on a project to improve the marketing and public image of L. I. hard quahogs. *In* Collection of reports prepared under subcontract with the Suffolk County Planning Department pursuant to a grant (NA-84-EA-D-00062) awarded to the County of Suffolk, Office the County Executive, by the NMFS under the Saltonstall-Kennedy Act of 1954. Suffolk County Planning Dep., Happauge, NY. 9 p. + 10 addendum pages.

_____ . 1992. Distribution and Abundance of Fishes and Invertebrates in Gulf of Mexico Estuaries, Volume I: Data Summaries. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Md.

_____ . 1997. Anuario estadistico de pesca. SEMARNAP (Secretaria de Medio Ambiente Recursos Naturales y Pesca). Mexico City, p. 241.

Antoli, F. V., and A. Garcia-Cubas, A. 1985. Sistematica y ecologia de moluscos en las lagunas costeras Carmen y Machona, Tabasco, Mexico. An. Inst. Cienc. Del Mar. Y Limnol. Univ. Nat. Auton. Mexico 12(1): 145–198.

Baldwin, R. B., W. Mook, N. H. Hadley, R. J. Rhodes, and R. J. Devoe. 1995. Construction and operations manual for a tidal powered upweller nursery system. S.C. Sea Grant Cons., Charleston, 44 p.

Baqueiro, E. 1997. The molluscan fisheries of Mexico. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 2, Pacific coast and supplemental topics, p. 1–17. U.S. Dep. Commer., NOAA Tech. Rep. 128.

Barber, J. W., and H. Howe. 1844. Historical collections of the State of New Jersey. Publ. by Benjamin Olds, New Haven, Conn., 520 p.

Barile, D. D. 1988. History of the Indian River Lagoon. *In* D. Busby (Editor), An overview of the Indian River quahoging industry and the Indian River Lagoon, p. 7–8. Fla. Sea Grant Ext. Prog. Tech. Pap. 44.

_____ and W. Rathjen. 1986. Report on the rainfall event of September and October 1985 and the impact of storm discharge on salinity and the quahog population (*Mercenaria mercenaria*) of the Indian River lagoon. Mar. Resour. Counc., Fla. Inst. Tech., Melbourne, Fla., 171 p.

Bates, T. 1999. Heat wave helps clams. Asbury Park Press, July 9.

Belding, D. L. 1912. The quahog fishery of Massachusetts, including the natural history of the quahog and a discussion of quahog farming. Commonw. Mass., Mar. Fish. Ser. 2, 41 p.

_____ . 1931. The quahog fishery of Massachusetts. Mass. Dep. Conserv., Div. Fish. Game, Mar. Fish. Serv. 2, 41 p.

Black, J. A., and J. Kassner. 1988. Small forms and brown tides. The Dolphin, p. 4–5.

Boyd, J. R. 1991. The Narragansett Bay shellfish industry: A historical perspective and an overview of problems in the 1990s. *In* M. A. Rice, M. Grady, and M. L. Schwartz (Editors), Proceedings of the first Rhode Island shellfisheries conference, p. 171–185. R.I. Sea Grant.

Boynton, W. 1970. The commercial fisheries of Chincoteague Bay — past, present and future. *In* Assateague Ecological Studies, Part J, p. 357–374. Nat. Resour. Inst., Univ. Maryland, Coll. Park, Contr. 446.

Brooks, W. K. 1879. The development of the American oyster. Stud. Biol. Lab., Johns Hopkins Univ. IV:1–104.

Burrell, V. G., Jr. 1977. Mortalities of oysters and hard clams associated with heavy runoff in the Santee River system, South Carolina in the spring of 1975. Proc. Natl. Shellfish. Assoc. 67:35–43.

_____ . 1997. Molluscan shellfisheries of the South Atlantic region of the United States. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition and future of the molluscan fisheries of North and Central America and Europe. Vol. 1, Atlantic and Gulf coasts, p. 171–185. U. S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

Busby, D. S. 1988. Overview of the industry. *In* D. Busby (Editor), An overview of the Indian River quahoging industry and the Indian River Lagoon, p. 1–6. Fla. Sea Grant Ext. Prog., Tech. Pap. 44.

Caddy, J. F., and R. A. Chandler. 1976. Historical statistics of landings of inshore species in the Maritime Provinces 1947–1973. Fish. Mar. Serv., Environ. Can., Tech. Rep. 639, 240 p.

Castagna, M. 1985. Farming of the northern hard clam *Mercenaria mercenaria* (Linne) in Va. J. Shellfish Res. 5(1):33 (Abstract).

_____ and D. S. Haven. 1972. The hard clam industry. *In* V. G. Burrell, Jr., M. Castagna, and R. K. Dias (Editors), A study of the commercial and recreational fisheries of the eastern shore of Virginia, Accomack and Northampton Counties, p. 64–82. Spec. Rep. Appl. Mar. Sci. and Ocean Eng. 20. Va. Inst. Mar. Sci., Gloucester Point.

_____ and J. Kraeuter. 1977. Mercenaria culture using stone aggregate for predator protection. Proc. Natl. Shellfish. Assoc. 67:1–6.

_____ and _____ . 1981. A manual for growing the hard clam, Mercenaria. *In* Spec. Rep., Appl. Mar. Sci. Ocean Engr. 249. Va. Inst. Mar. Sci., Gloucester Point, 107 p.

Castillo, C., E. Baqueiro, M. M. Huchin, and M. C. Medina. 1988. Historia actual y situation actual de las pesquerias de almeja en Golfo de Mexico. Instituto Nacional de la Pesca. Los Recursos Pesqueros del Pais, p. 391–397.

Chestnut, A. F. 1953. Studies of the North Carolina clam industry. Natl. Shellfish. Assoc. 1951 Convention Addresses, p. 85–88.

Coastal Fisheries Act. 1924. Act No. 623. Code of laws of South Carolina 1016–1043.

Coastal Fisheries Laws. 1959. Act No. 259. Statutes at large of South Carolina. 439–440.

Colson, S., and L. N. Sturmer. 2000. One shining moment known as Clamelot: the Cedar Key story. J. Shellfish. Res. 19(1):477–480.

Darling, W. S. 1984. Quahoging out of Rock Harbor 1890–1930. Privately printed by author. Thompson's Printing Co., Orleans, Mass., 60 p.

Davis, H. C. 1969. Shellfish hatcheries — present and future. Trans. Am. Fish. Soc. 98(4):743–750.

Desbonnet, A., and V. Lee. 1991. Historical trends: Water quality and fisheries, Narragansett Bay. Univ. R.I. Coast. Resour. Cent., Contrib. 100, and Natl. Sea Grant Publ. RIU-T-91-001, 101 p.

Dillon, R. T., Jr., and J. J. Manzi. 1987. Hard clam, *Mercenaria mercenaria* brood stocks: Genetic drift and loss of rare alleles without reduction in heterozygosity. Aquaculture 60: 99–105.

_____ and _____ . 1988. Enzyme heterozygosity and growth rate in nursery populations of *Mercenaria mercenaria*. J. Exp. Mar. Biol. Ecol. 116:79–86.

Dugas, R. J. 1980. A status report on commercial clamming efforts in Louisiana. Louisiana Dep. Wildl. Fish., Tech. Bull. 31:23–32.

Eldridge, P. J., W. Waltz, R. C. Gracy, and H. H. Hunt. 1976. Growth mortality rates of hatchery seed clams, *Mercenaria mercenaria*, in protected trays in waters of South Carolina. Proc. Natl. Shellfish. Assoc. 66:13–20.

_____ , A. G. Eversole, and J. M. Whetstone. 1979. Comparative survival and growth rates of hard clams *Mercenaria mercenaria*, planted in trays subtidally and intertidally at varying densities in a South Carolina estuary. Proc. Natl. Shelf. Assoc. 69:30–39.

Eversole, A. G., C. J. Kempton, N. H. Halley, and W. R. Buzzi. 1996. Comparison of growth, survival and reproductive success of diploid and triploid *Mercenaria mercenaria*. J. Shellfish Res. 15(3):69

Fenton, R. 2001. New Jersey shellfish culture. Talk presented at Shellfish Culture and the Environment Symposium. Cumberland College, Vineland, N.J.

Fiedler, R. H. 1940. Fisheries industries of the United States 1938. U.S. Dep. Inter., Fish Wildl. Serv., Admin. Rep. 37, p. 169–554.

Fleet, S. 1992. R. I. 89-694. Quahog diggers demand ban on commercial diving. Commer. Fishing News, Mar.:27A.

Ford, S. E. 1997. History and present status of molluscan fisheries from Barnegat Bay to Delaware Bay. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe, Vol. 1, Atlantic and Gulf coasts, p. 119–140. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

Freeman, J. 1807. A description of Dukes County in 1807. Mass. Hist. Soc.

Ganz, A., A. Valliere, M. Gibson, and N. Lazar. 1999. Narragansett Bay quahaug management plan. R.I. Dep. Environ. Manage., Div. Fish Wildl., Coastal Fish. Lab., Wakefield, 93 p.+ appendix.

Garcia-Cubas, A. 1981. Moluscos de un sistema lagunar tropical en el sur del Golfo de Mexico (Laguna de Terminos, Campeche). An. Inst. Cienc. Del Mar y Limnol. Univ. Nat. Auton. Mexico. Publ. Esp. 294:1–182.

_____ and M. Reguero. 1990. Moluscos del sistema lagunar Tupilco-Ostion, Tabasco, Mexico: Sistematica y ecologia. An. Inst. Cienc. Del Mar y Limnol. Univ. Nat. Auton. Mexico 17(2):309–343.

Gates, J. M. 1991. Quahog market trends. *In* M. A. Rice, M. Grady, and M. L. Swartz (Editors), Proceedings of the first Rhode Island shellfisheries conference, p. 93–103. Univ. R.I. Sea Grant Prog., Narragansett.

Gatewood, J. B., and B. J. McCay. 1990. Comparison of job satisfaction in six New Jersey fisheries: implications for management. Hum. Organ. 49(1):14–25.

Glancy, J. 1943. Untitled. *The Fishing Gazette* 60(13):34–35, 88.

Godcharles, M. F., and W. C. Jaap. 1973. Exploratory quahog survey of Florida nearshore and estuarine waters with commercial hydraulic dredging gear. Fla. Dep. Nat. Resour., Mar. Res. Lab., Prof. Pap. Ser. 21, 77 p.

Gracy, R. C., W. J. Keith, and R. J. Rhodes. 1978. Management and development of the shellfish industry in South Carolina. S.C. Wildl. Mar. Resour. Dep. Tech. Rep. 28, 23 p.

Guthrie, J. F., and C. W. Lewis. 1982. The quahog-kicking fishery of North Carolina. Mar. Fish. Rev. 44(1):16–21.

Hadley, N. H., R. T. Dillon, Jr., and J. J. Manzi. 1991. Realized heritability of growth rate in the hard clam *Mercenaria mercenaria*. Aquaculture 93:109–119.

_____ , J. J. Manzi, A. G. Eversole, R. T. Dillon, C. E. Battey, and N. M. Peacock. 1997. A manual for the culture of the hard clam *Mercenaria* spp. in South Carolina. S.C. Sea Grant Consort., Charleston, 135 p.

Haven, D. S., W. J. Hargis, Jr., J. G. Loesch, and J. P. Whitcomb. 1975. The effect of Tropical Storm Agnes on oysters, hard clams, soft clams and oyster drills. Chesapeake Res. Consort. Publ. 34: D170–D208.

_____ , J. P. Whitcomb, and O. C. Davis. 1979. A mechanical escalator for live oysters and shell. Mar. Fish. Rev. 41(12):17–20.

Heaton, C. J. E. 1972. South Carolina early laws and statutes pertaining to game, fish, wildlife and conservation. Manu. Spec. Collection Clemson Univ. Library #346976, 131 p.

Hickey, J. M. 1983. Assessment of quahog stocks in contaminated waters of southeastern Massachusetts. Mass. Dep. Fish., Wildl. Rec. Vehicles Publ. 13636-92-50-6-84-C.R. Boston, Mass., 31 p.

Hsiao, Y., T. Johnson, and J. E. Easley. 1986. An economic analysis of a potential overfishing problem: the North Carolina hard quahog fishery. UNC Sea Grant Publ. UNC-SG-86-11.

Ingersoll, E. 1881. The oyster industry. *In* G. Brown Goode (Editor), The history and present condition of the fishery industries, U.S. Gov. Print. Off., Wash., 251 p.

_____ . 1887. The oyster, scallop, quahog, mussel, and abalone industries. *In* G. B. Goode and a staff of Associates (Editors), The fisheries and fishery industries of the United States. Sect. II, p. 507–626. U.S. Gov. Print Off., Wash.

Jenkins, J. B., A. Morrison, and C. L. MacKenzie, Jr. 1997. The molluscan fisheries of the Canadian Maritimes. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe, Vol. 1, Atlantic and Gulf coasts, p. 15–44. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

Jones, D. S., I. R. Quitmyer, W. S. Arnold, and D. C. Marelli. 1990. Annual shell banding, age, and growth rate of hard clams (*Mercenaria* spp.) from Florida. J Shellfish Res. 9: 215–225.

Joseph, J. W. 1989. Inventory of New Jersey's estuarine shellfish resources. N.J. Dep. Environ. Protect., Div. Fish, Game, Wildl. Completion Rep. to NOAA, NMFS, Trenton, N.J., 75 p.

Kadri, J. 1991. A raw deal: combined sewer outflow pollution in Narragansett Bay. *In* M. A. Rice, M. Grady, and M. L. Swartz (Editors), Proceedings of the first Rhode Island shellfisheries conference, p. 43–57. R.I. Sea Grant, Narragansett.

Kassner, J. 1988. The consequence of baymen: the hard clam (*Mercenaria mercenaria* Linne) management situation in Great South Bay, New York. J. Shellfish Res. 7(2):289–293.

_____ and J. A. Black. 1982. Efforts to stabilize a coastal inlet: A case study of Moriches Inlet, New York. Shore and Beach, April: 21–29.

Kellogg, J. L. 1901. Clam and scallop industries of New York State. Univ. State N.Y., Albany. N.Y. State Mus. Bull. 43 (8):605–629.

_____ . 1910. The clam problem and clam culture. *The Fishing Gazette* 27(30).

_____ . 1917. Artificial culture of the clam said to be full of possibilities. *The Fishing Gazette* 34(30):929–930.

Kennish, M. J., M. B. Roche, and T. R. Tatham. 1984. Anthropogenic effects on aquatic communities. *In* M. J. Kennish, and R. A. Lutz (Editors), Ecology of Barnegat Bay, New Jersey, p. 318–338. Springer-Verlag, N.Y.

Kerswill, C. J. 1949. Effects of water circulation on quahogs and oysters. J. Fish. Res. Board Can. 7(9):545–551.

Kobbe, G. 1982. New Jersey Coast and Pines. Reprint of 1889 edition. P.O. Box 352. New York, Walker News, Inc.

Kraeuter, J. N., and M. Castagna. 1998. A century of fish culture: The rise of commercial clam culture. Convention Address, World Aquaculture Society meeting. Feb.15–19, 1998. Las Vegas, Nevada.

Langley, L. 1998. Shrimping outshines oysters, clam season. Post Courier. Charleston, S.C. Sept. 11, 1998, p. 3b.

Leonard, T. H. 1923. From Indian trail to electric rail. Atl. Highlands [N.J.] Historical Soc., 665 p.

Loosanoff, V. L. 1945. Precocious gonad development in oysters induced in midwinter by high temperature. Science (Wash.) 102: 124–125.

_____ . 1959. You, too, can now hatch clams. Prog. Fish-Cult. 21(1):35.

_____ and H. C. Davis. 1963. Rearing of bivalve mollusks. *In* F. S. Russell (Editor),

Advances in Marine Biology, p. 1–36. Acad. Press, N.Y.

Low, R. A. 1998. South Carolina Marine Fisheries, 1996. S.C. Dep. Nat. Resour., Mar. Resour. Div., Off. Fish. Manage., Data Rep. 27, 78 p.

Lunz, G. R. 1944. Special study of the marine fisheries resources of South Carolina. S.C. State Plan. Board Bull. 14, 61 p.

_____ . 1949. The clam situation in South Carolina. Contr. Bears Bluff Lab. Wadmalaw Island 6, 4 p.

_____ . 1960. Report of South Carolina Wildlife Resources Department. Div. Commer. Fish. FY 1959–1960, p. 58–60.

_____ . 1963. Annual Report Division Commercial Fisheries. Annual Rep. S.C. Wildl. Res. Dep. 1962–1963:78–81.

MacBride, E. W. 1912. Oyster culture and clam fishing, Prince Edward Island. *In* Contributions to Canadian biology, being studies from the Marine Biological Stations of Canada 1906–1910, p. 217–220. C. H. Parmelee, Printer, Ottawa.

MacKenzie, C. L., Jr. 1977. Predation on hard clam (*Mercenaria mercenaria*) populations. Trans. Am. Fish. Soc. 106:530–537.

_____ . 1992a. The fisheries of Raritan Bay. Rutgers Univ. Press, New Brunswick, N.J., 304 p.

_____ . 1992b. Shellfisheries on Martha's Vineyard. The Dukes County Intelligencer [Dukes county Hist. Soc., Mass.] 34(1):1–34.

_____ . 1997a. The molluscan fisheries from Massachusetts Bay through Raritan Bay. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 1, Atlantic and Gulf coasts, p. 87–117. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

_____ . 1997b. The molluscan fisheries of Chesapeake Bay. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe, Vol. 1, Atlantic and Gulf coasts, p. 141–169. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

_____ and V. G. Burrell, Jr. 1997. Trends and status of molluscan fisheries on North and Central America and Europe – a synopsis. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe, Vol. 1, Atlantic and Gulf coasts, p. 1–14. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

_____ and R. Pikanowski. 2000. Quahog populations explode after starfish populations crash. Shellfish World 1(4):6–7.

_____ , A. Morrison, D. L. Taylor, V. G. Burrell, Jr., W. S. Arnold, and A. T. Wakida-Kusunoki. 2002. Quahogs in eastern North America: part I, biology, ecology, and historical uses. Mar. Fish. Rev. 64(2):1–55.

MacPhail, J. S. 1961. A hydraulic escalator harvester. Fish. Res. Board Can. Bull. 128, 24 p.

Manzi, J. J., V. G. Burrell, Jr., and H. Q. M. Clawson. 1981. Commercialization of hard clam (*Mercenaria mercenaria*) aquaculture in South Carolina: preliminary report. J. World Maricul. Soc. 12:181–195.

_____ and M. Castagna (Editors). 1989. Clam culture in North America. Elsevier Sci. N.Y., 447 p.

_____ , N. H. Halley, and R. T. Dillon. 1991. Hard clam, *Mercenaria mercenaria*, brood stocks: growth of selected hatchery stocks and their reciprocal crosses. Aquaculture V 94:17–26.

McCay, B. J. 1984. The pirates of Piscary: Ethnohistory of illegal fishing in New Jersey. Ethnohistory 31(1):17–37.

_____ . 1988. Muddling through the clam beds: cooperative management of New Jersey's hard clam spawner sanctuaries. J. Shellfish Res. 7(2):327–340.

_____ and W. P. Jenks, III. 1997. The importance of shellfisheries to coastal communities. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 2, Pacific Coast and supplemental topics, p. 145–155. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 127.

McCloy, T. W., and J. W. Joseph. 1985. Inventory of New Jersey's estuarine shellfish resources. N.J. Dep. Environ. Prot., Div. Fish, Game, Wildl. Completion Rep. to NOAA, NMFS, Trenton, N.J., 28 p.

McHugh, J. L. 1991. The hard clam fishery past and present. *In* J. R. Shubel, T. M. Bell, and H. H. Carter (Editors), The Great South Bay, p. 55–63. State Univ. N.Y. Press, Albany.

Moonsammy, R. Z., D. S. Cohen, and M. T. Hufford. 1987. Living with the landscape: Folklife in the environmental subregions of the Pinelands. *In* R. Z. Moonsammy, R. Z., D. S. Cohen, and L. E. Williams (Editors), Pinelands Folklife, p. 65–230. Rutgers Univ. Press, New Brunswick, N.J.

Peterson, C. H., H.C. Summerson, and S. R. Fegley. 1987. Ecological consequences of mechanical harvesting of clams. Fish. Bull. 86:281–298.

Porter, H. J., and A. F. Chestnut. 1962. The offshore clam fishery of North Carolina. Proc. Natl. Shellfish. Assoc. 51:67–73.

Pratt, S. D. 1988. Status of the hard quahog fishery in Narragansett Bay. Final Rep. NBP-88-07 for Narragansett Bay Project. Grad. School Oceanogr. Univ. R.I., Narragansett, 89 p.

_____ , M. A. Rice, and A. R. Ganz. 1992. Species profile of the quahog in Rhode Island. R.I. Sea Grant, Univ. R.I., Narragansett, 117 p.

Prytherch, H. F. 1924. Experiments in the artificial propagation of oysters. App. 11 to Rep. U.S. Fish. for 1923, 1–14.

Red Bank Register. 1935. October 17.

Reguero, M., and A. Garcia-Cubas. 1989. Moluscos de la Laguna de Alvarado, Veracruz, Mexico: sistematica y ecologia. An. Inst. Cienc. Del Mar y Limnol. Univ. Nat. Auton. Mexico 16(2):279–306.

_____ and _____ . 1991. Moluscos de la Laguna Camaronera, Veracruz, Mexico: Sistematica y ecologia. An. Inst. Cienc. Del Mar y Limnol. Iniv. Nat. Auton. Mexico 18(1):289–328.

_____ and _____ . 1993. Moluscos de la Laguna de Pueblo Viejo, Veracruz, Mexico: Sistematica y ecologia. An Inst. Cienc. Del Mar y Limnol. Univ. Nat. Auton. Mexico 20(1):77–104.

_____ , _____ , and G. Zuniga. 1991. Moluscos de la Laguna Tampamachoco, Veracruz, Mexico: Sistematica y ecologia. An Inst. Cienc. Del Mar y Limnol. Univ. Nat. Auton. Mexico 18(2):289–328.

Rhodes, R. J., W. J. Keith, P. J. Eldridge, and V. G. Burrell, Jr. 1977. An empirical evaluation of the Leslie-Delury method to estimating hard clam, *Mercenaria mercenaria*, abundance in the Santee River estuary, South Carolina. Proc. Natl. Shellfish. Assoc. 67: 44–52.

Rice, M. A., A. Valliere, and A. Caporelli. 2000. A review of shellfish restoration and management projects in Rhode Island. J. Shellfish Res. 19(1):401–408.

Ropes, J. W., and C. E. Martin. 1960. The abundance and distribution of hard clams in Nantucket Sound, Massachusetts, 1958. U.S. Fish Wildl. Serv., Spec. Sci. Rep.-Fish. 354:1–11.

Ryther, J. H. 1988. Untitled. *In* D. Busby (Editor), An overview of the Indian River quahoging industry and the Indian River Lagoon, p. 14. Fla. Sea Grant Ext. Prog., Tech. Pap. 44.

S.C. Mar. Res. Div. 1996. Marine fisheries and related laws (reprinted from the code of laws of South Carolina). Charleston, 93 p.

S.C. State Board of Fisheries. 1926. Annual report. Columbia, 11 p.

_____ . 1927. 21st annual report. Year ending 31st December 1927, 18 p.

_____ . 1931. 25th annual report. Year ending 31st December 1931, 18 p.

_____ . 1934. 28th Annual Report for the year ending 30 June 1934. Columbia, 20 p.

S.C. Wildl. Mar. Resour. Dep. 1978. Report for the fiscal year July 1, 1977–June 30, 1978. Columbia, 113 p.

_____ . 1980. Report of the South Carolina Wildlife and Marine Resources Department for Fiscal year 1980. Columbia, 113 p.

_____ . 1982. Report for fiscal year July 1, 1981–June 30, 1982. Columbia, 109 p.

_____ . 1984. Report for the fiscal year July 1, 1983–June 30, 1984. Columbia, 87 p.

_____ . 1986. Report of the South Carolina Wildlife and Marine Resources Department. Rep. FY July 1, 1985–June 30, 1986, Columbia, 88 p.

_____ . 1988. Report of the South Carolina Wildlife and Marine Resources Department. Rep. FY July 1, 1987–June 30, 1988, Columbia, 88 p.

Schroeder, W. C. 1924. Fisheries of Key West and the clam industry of southern Florida. U.S. Bur. Fish. Doc. 962, 74 p.

Sim, R. J. 1949. Pages from the past of rural New Jersey. N.J. Agric. Soc. Trenton, 121 p.

Smith, S. 1690. The colonial history of New Jersey. William S. Sharp, Trenton, p. 167–189.

Spaulding, M. H. 1906. A preliminary report on the distribution of the scallops and clams in the Chandeleur Island Regions, Louisiana. Bull. Gulf Biol. Sta. 6:29–43.

Stafford, J. 1912. Conservation of the oyster. *In* Sea-fisheries of eastern Canada, p. 25–49. Commiss. Conserv., Can., Printed by The Mortimer Co., Ottawa.

Sturmer, L. N., E. Quesenberry, and D. E. Vaughan. 1997. Development of hard clam aquaculture on Florida's west coast: from training to production to a sustainable industry (Abstract). World Aquacult. Soc. Book of Abstr., p. 443–444.

Taylor, D. L. 1995. North Carolina Fishery Management Plan hard clam. Unpubl. Rep., N.C. Dep. Environ., Health, Nat. Resour., Div. Mar. Fish., Morehead City, 38 p.

Tester, P. A., R. P. Stumpf, and P. K. Fowler. 1988. Red tide, the first occurrence in North Carolina waters: An overview. Proc. Oceans

88 Conf. Baltimore, Md., Oct 31–Nov. 2, 1988.
Townsend, C. H. 1901. Statistics of the fisheries of the middle Atlantic states. U.S. Comm. Fish Fish., Part XXVI, Rep. Comm. 1900: 195–310.
Tressler, D. K., and J. M. Lemon. 1951. Marine products of commerce. Reinhold Publ. Corp., N.Y., 782 p.
Turgeon, D. D., J. F. Quinn, Jr., A. E. Bogan, E. V. Coan, F. G. Hochberg, W. G. Lyons, P. M. Mikkelsen, R. J. Neves, C. F. E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F. G. Thompson, M. Vecchione, and J. D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. Am. Fish. Soc. Spec. Publ. 26, 2nd ed., 526 p.
Wells, W. F. 1927. Report of the experimental shellfish station. Rep. N.Y. State Conserv. Dep. No. 16:1–22.

Errata

The abstract in Part I of this quahog article, misstated the Mexican State that leads in quahog production. It is the Tabasco, not Campeche.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

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Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

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Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

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